National Park Service
U.S. Department of the Interior

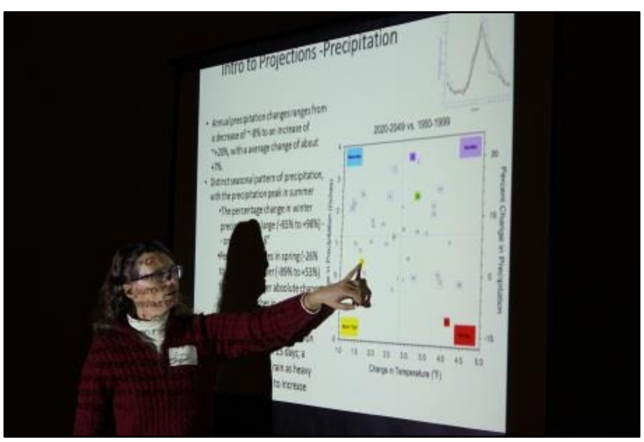
Natural Resource Stewardship and Science

Resource Management and Operations in Central North Dakota

Climate Change Scenario Planning Workshop Summary

November 12-13, 2015, Bismarck, ND

Natural Resource Report NPS/NRSS/NRR—2016/1262



ON THE COVER
Workshop participants worked collaboratively to examine possible scenarios under ongoing climate change to help inform future management and planning decisions. NPS photos.

Resource Management and Operations in Central North Dakota

Climate Change Scenario Planning Workshop Summary

November 12-13, 2015, Bismarck, ND

Natural Resource Report NPS/NRSS/NRR—2016/1262

Nicholas Fisichelli[1,2]*, Gregor Schuurman[1], Amy Symstad[3], Andrea Ray[4], Jonathan Friedman[5], Brian Miller[5,6], Erika Rowland[7]

[1]U.S. National Park Service
Natural Resource Science and Stewardship
Climate Change Response Program
1201 Oak Ridge Drive
Fort Collins, CO 80525

[2]Schoodic Institute at Acadia National Park
Forest Ecology Program
PO Box 277
Winter Harbor, ME 04693
*current address

[3]U.S. Geological Survey
26611 U.S. Highway 385
Northern Prairie Wildlife Research Center
Hot Springs, SD 57747

[4]National Oceanic and Atmospheric Administration
Earth System Research Lab, Physical Sciences Division
R/PSD1, 328 Broadway
Boulder, CO 80305

[5]U.S. Geological Survey
Fort Collins Science Center
2150 Centre Avenue, Bldg C
Fort Collins, CO 80526

[6]Colorado State University
Natural Resource Ecology Laboratory
and North Central Climate Science Center
Fort Collins, CO 80523

[7]Wildlife Conservation Society
332 Del Chadbourne Road
Bridgton, ME 04009

August 2016

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

This report is available in digital format from the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Fisichelli, N., G. Schuurman, A. Symstad, A. Ray, J. Friedman, B. Miller, E. Rowland. 2016. Resource management and operations in central North Dakota: Climate change scenario planning workshop summary November 12-13, 2015, Bismarck, ND. Natural Resource Report NPS/NRSS/NRR—2016/1262. National Park Service, Fort Collins, Colorado.

NPS 909/133729, August 2016

Contents

Page

Figures

Figures (continued)

Page

Tables

Appendices

Abstract

The *Scaling Climate Change Adaptation in the Northern Great Plains through Regional Climate Summaries and Local Qualitative-Quantitative Scenario Planning Workshops* project synthesizes climate data into 3-5 distinct but plausible climate summaries for the northern Great Plains region; crafts quantitative summaries of these climate futures for two focal areas; and applies these local summaries by developing climate-resource-management scenarios through participatory workshops and, where possible, simulation models. The two focal areas are central North Dakota and southwest South Dakota (Figure 1). The primary objective of this project is to help resource managers and scientists in a focal area use scenario planning to make management and planning decisions based on assessments of critical future uncertainties.

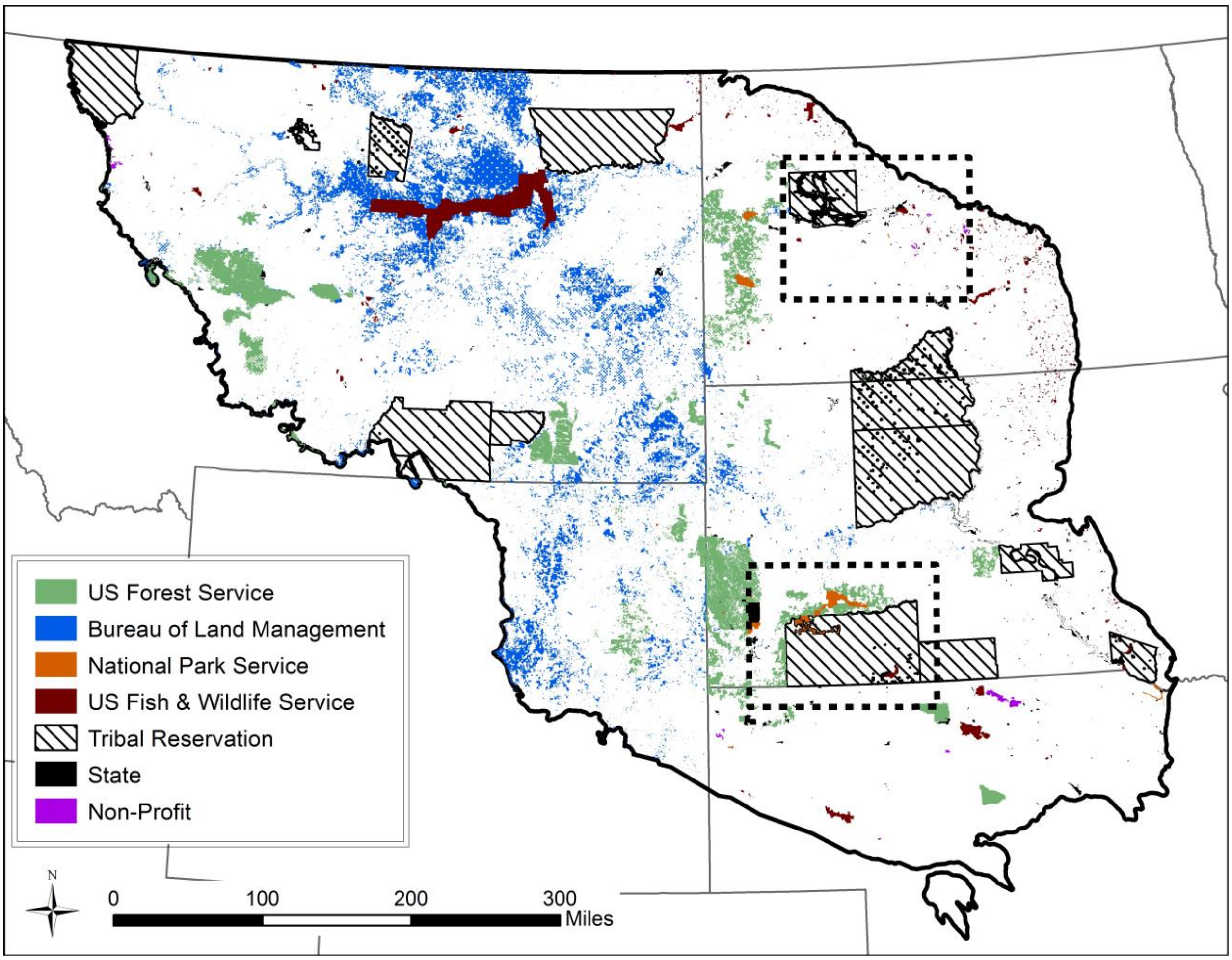


Figure 1. Map of Northern Great Plains area (solid black outline) included in the Scaling Climate Change Adaptation in the Northern Great Plains through Regional Climate Summaries and Local Qualitative-Quantitative Scenario Planning Workshops project. Two focal areas for the project (central North Dakota and southwest South Dakota) are shown in dashed rectangles.

This report summarizes project work for public and tribal lands in the central North Dakota focal area, with an emphasis on Knife River Indian Villages National Historic Site. The report explains scenario planning as an adaptation tool in general, then describes how it was applied to the central North Dakota focal area in three phases. Priority resource management and climate uncertainties were identified in the orientation phase. Local climate summaries for relevant, divergent, and challenging climate scenarios were developed in the second phase. In the final phase, a two-day scenario planning workshop held November 12-13, 2015 in Bismarck, ND, featured scenario development and implications, testing management decisions, and methods for operationalizing scenario planning outcomes.

Acknowledgements

We thank the workshop participants for their insights, participation, and tremendous energy. Funding for this project was provided by the Department of Interior North Central Climate Science Center, and in-kind contributions were made by the National Park Service Climate Change Response Program, National Oceanic and Atmospheric Administration/Earth Sciences Research Laboratory Physical Sciences Division, U.S. Geological Survey Northern Prairie Wildlife Research Center, and Wildlife Conservation Society. We thank J. Star and H. Hartmann for materials and ideas and M. Talbert for assistance with processing climate data. We acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the WCRP's Working Group on Coupled Modelling (WGCM) for their roles in making available the WCRP CMIP3 multi-model dataset, and the "Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections" archive. Support of the WCRP dataset is provided by the Office of Science, U.S. Department of Energy.

Introduction

Uncertainties are inherent to planning around complex environmental issues (Gregory et al. 2012) and are addressed by resource managers in a variety of ways. In recent years, awareness of the largely uncontrollable uncertainty surrounding climate change, not knowing precisely when, where, and how climate change effects will unfold, has had an increased influence in decision-making (Peterson et al. 2003, Rowland et al. 2014). Understanding and working with uncertainties, especially those arising from external drivers like climate change, will ultimately empower decision-makers to take action now while planning for the future.

> *"Scenarios are stories about the ways that the world might turn out tomorrow…that can help us recognize and adapt to changing aspects of our current environment."*
>
> -Peter Schwartz,
> *The Art of the Long View*

Scenario planning is a flexible tool that is useful for understanding potential climate change implications and uncertainties in a way that is relevant to resource and landscape management. Scenario planning facilitates decision-making by providing a structured process for building and thinking about a range of possible futures that managers may face, in order to consider not just what is likely, but also what is plausible, relevant, and highly consequential (Figure 2; NPS 2013). This collaborative approach uses science at management-relevant scales and can include social and political factors affecting decisions. The process encourages long-term science-management partnerships by providing a setting to consider the breadth of uncertainty around climate impacts and their interaction with other stressors, and the opportunity to explore a range of innovative responses. Using scenarios as part of planning can offer benefits in the form of (1) an increased understanding of key uncertainties facing resource management and operations, (2) the incorporation of alternative perspectives into resource management planning, and (3) an improved capacity for adaptive management to achieve desired conditions.

A crucial part of climate change scenario planning is assessing and understanding relevant climate uncertainties, which are expressed as the range of results from projections for a variety of climate variables. Although this range of projected futures provides resource managers a realistic representation of the uncertainties about future climate, the volume of information can be daunting for managers trying to incorporate climate change into their planning. Science partners can help managers winnow down plausible climate futures by (1) asking and determining which climate variables and aspects of those variables are critical forces in shaping focal resources, (2) evaluating uncertainty in these variables from their ranges represented in climate projections, and (3) synthesizing coherent climate summaries that cover a plausible range of futures for the key variables at the relevant spatial scale.

Climate summaries are made relevant to management by comparing climate projections to historical climate trends and weather events, then determining the consequences of plausible future climates for focal resources in the context of other stressors. NPS has developed and refined a qualitative scenario planning approach focused on expert opinion and synthesis of pre-existing science (NPS 2013). Managers are increasingly interested in using scenario planning for specific resource planning and actions; quantitative simulations may better assess complex resource dynamics and potential effects of management actions. The scenarios developed here for central North Dakota include both quantitative model output and expert opinion (Rowland et al. 2014).

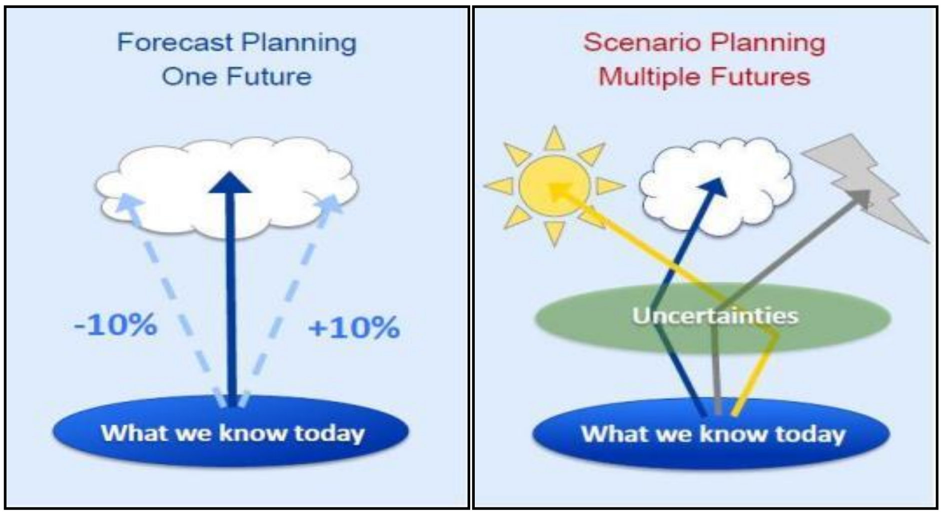


Figure 2. Scenarios offer a range of plausible future environments (right panel) – not predictions (left panel) – and provide a framework to support decisions under conditions that are uncertain and uncontrollable. Graphics from Global Business Network (GBN).

Project Timeline and Process

The central North Dakota focal area for which we provided local-scale adaptation support is largely privately owned, but federal, state, tribal, and non-governmental agencies all manage portions of this landscape (Figure 3). During an orientation phone call on April 27, 2015, we introduced the project to key management partners and identified additional information sources and stakeholders. To create relevant scenarios and focus the workshop on pertinent management concerns, we then met with a broader group of managers and scientists in a project orientation meeting on August 21, 2015 at the Audubon National Wildlife Refuge. The scenario planning workshop took place at the North Dakota Heritage Center & State Museum on November 12-13, 2015 in Bismarck, ND.

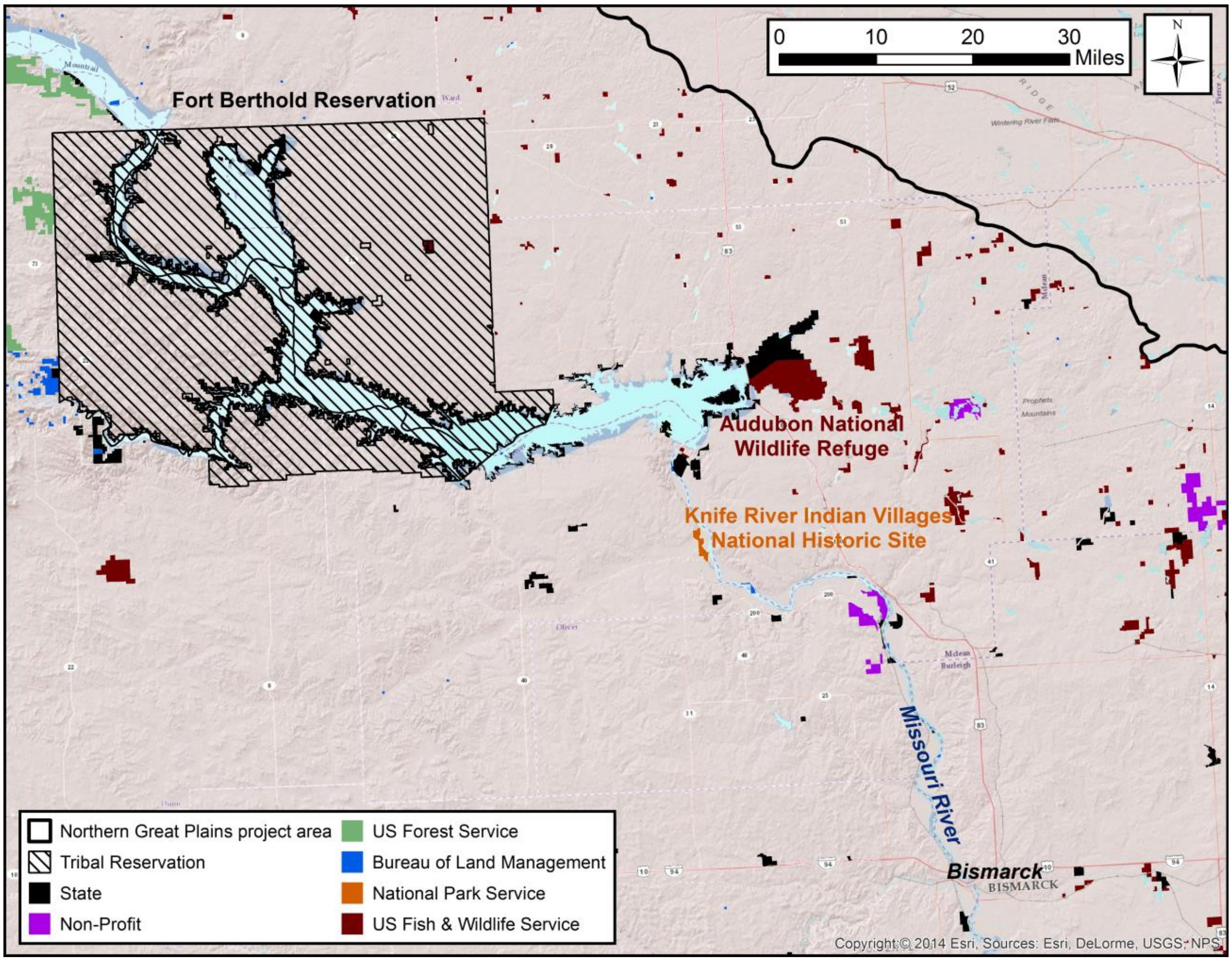


Figure 3. Central North Dakota project focal area.

Management Concerns and Focal Issues

The focal area overlaps with the Northern Plains Natural Heritage Area (NPNHA), a congressionally designated distinctive landscape celebrating the Mandan-Hidatsa homeland, Lewis and Clark, Sacagawea, and the Corps of Discovery. This landscape has a long history of human occupation and served as a center of trade for a variety of cultures. This history, which included a strong agricultural tradition and was shaped by the prairie, rivers, and riparian forests that comprised the landscape, continues today in that agriculture is still the prevalent land use, and there is a strong tradition of hunting, fishing, and dependence on the rivers. Moreover, preserving the evidence of this history and maintaining cultural and natural resources arising from the landscape are the focus of many of the agencies represented in this project.

Consequently, general management concerns in the focal area include the effects of riverbank erosion on archeological resources (material remains of human life or activities at least 100 years of age and capable of providing understanding of the past), effects of riparian dynamics on regeneration of riparian vegetation, preservation of cultural landscapes (geographic areas, including the cultural resources, plants and animals therein, associated with historic events, activities, or people), and invasive plants. Relevant climate change concerns include changes in precipitation, growing season length, soil moisture, and the flood regime of the Knife and Missouri Rivers. Participants noted that the past two decades have been relatively wet and expressed concern about a continuation of this trend and its consequences for executing key management actions like prescribed fire, or a shift to drier conditions and the consequent implications for vegetation and habitat management. For example, although conditions are warming, will the effective growing season length expand or will it contract because of moisture limitation? Additionally, participants raised concerns regarding the timing and magnitude of river flooding. Will flooding become more or less intense in early spring when snow and river ice melts, and will there be an increase in summer flooding related to heavy precipitation events? Finally, non-climate stressors identified include nitrogen deposition, non-native species invasions, and land development such as for energy extraction and agriculture. Three related focal topics, each with specific concerns, with broad appeal across agencies were identified and subsequently used for the workshop:

Archeological Sites

- impacts of erosion on significant cultural and archeological sites due to changes in river flow and bank slumping
- impacts of burrowing animals (northern plains pocket gophers) on *in situ* archeological deposits

Riparian Ecosystems

- restoring or preserving riparian forest dynamics (e.g., cottonwood tree regeneration)
- weighing tradeoffs between natural and cultural resource protection
- impacts to culturally significant plant species

Upland Grasslands

- interactions among climate, grazing, fire, nutrients, and invasive plants (including nitrogen-fixing legumes)
- climate-altered vegetation succession
- efficacy of current management practices under changing conditions
- impacts to culturally significant plant species

All of these focal topics impact cultural landscapes, a high-priority concern at historical sites.

Climate, Weather, and Resources: Variability, History, and the Future

The scenario planning workshop included science presentations on historical trends and future projections to provide valuable information to characterize conditions in central North Dakota (presentations by Karen Ryberg, U.S. Geological Survey (USGS); Greg Gust, National Weather Service; Amy Symstad, USGS; and Adnan Akyüz,

North Dakota State Climatologist). The climate of North Dakota is characterized by large temperature variations, dry winters, irregular summer precipitation, and persistent winds. North Dakota has experienced the greatest warming trend in the conterminous U.S. (annual average temperature +2.5 °F/century, 1895-2015; Figure 4).

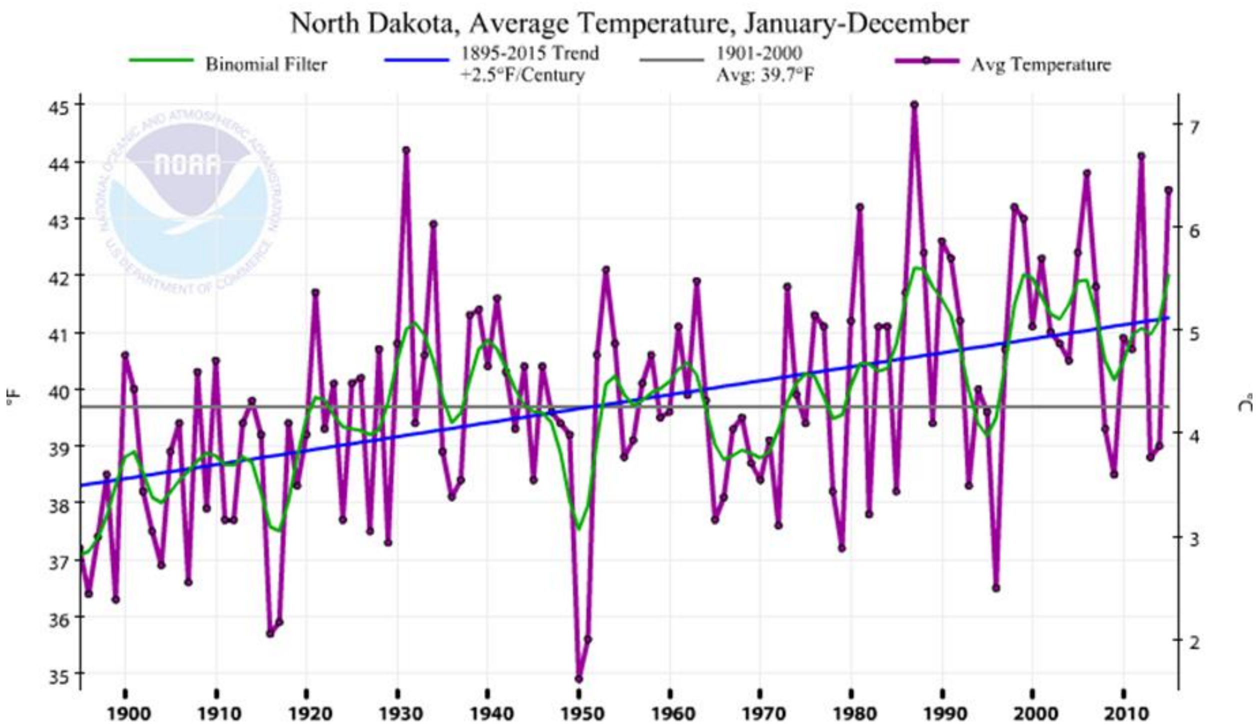


Figure 4. North Dakota annual average temperature (1895-2014). Figure from NOAA's National Centers for Environmental Information (http://www.ncdc.noaa.gov/cag/).

Most of the temperature increase during the last century was recorded in winter, +4.5°F increase in winter average temperature (also the highest in the country) compared to a +1.4°F increase in average summer temperature. Growing season length has expanded by 17.5 days/century (1881-2012). Directional changes in precipitation are generally much weaker than temperature, with patterns characterized by interannual and decadal variability. For example, tree ring data (a proxy for precipitation) for an area just north and east of the project area indicate strong variability in spring precipitation patterns over the past several hundred years, including multiple periods as wet as the early 2000s and multiple periods likely drier than the 1930s (Figure 5; Ryberg 2015).

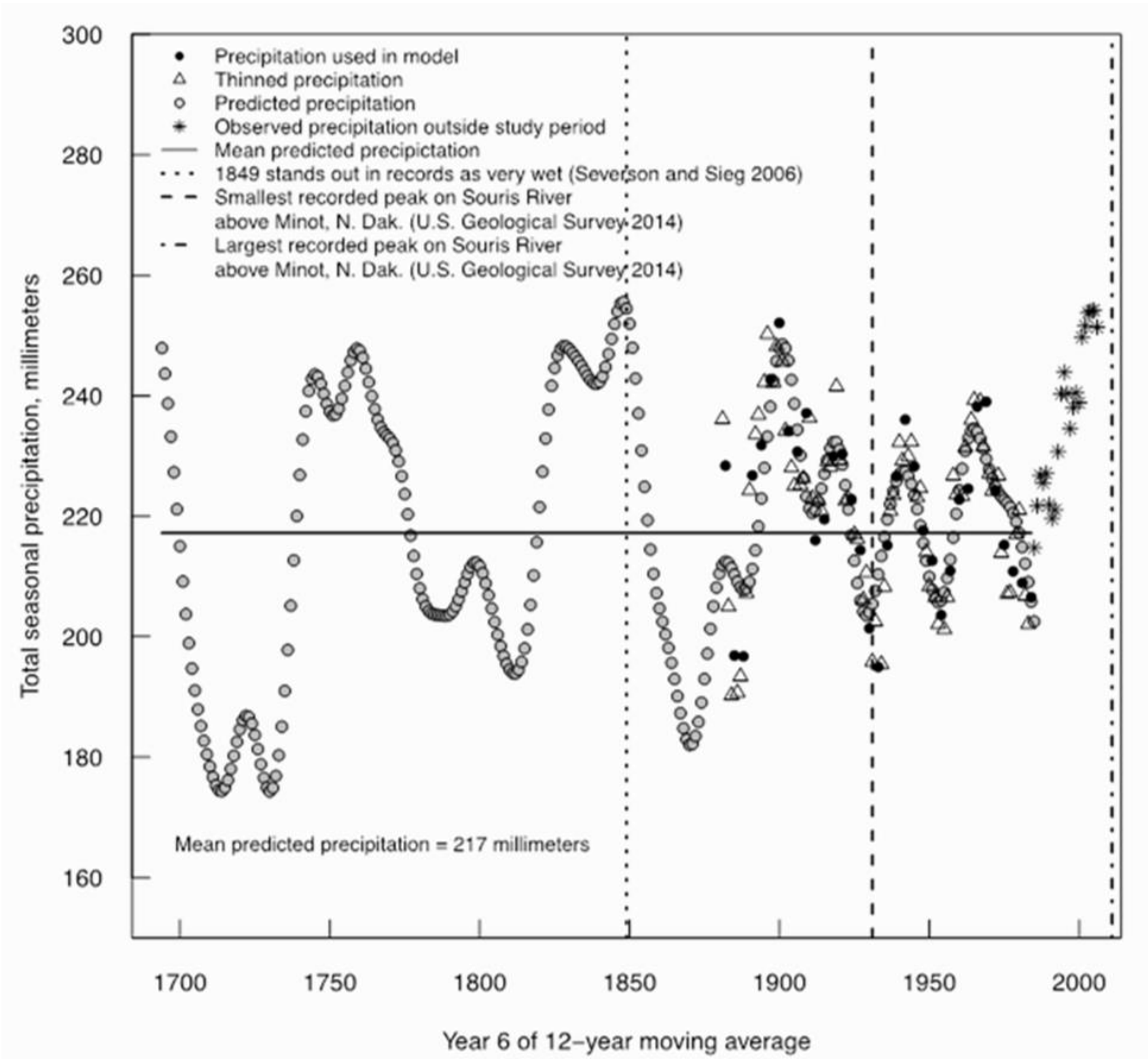


Figure 5. Spring (March-June) precipitation, approximately representing north-central North Dakota and the U.S. portion of the Red River Basin. Reconstructed precipitation (1700-1990, gray filled circles) is based on tree-ring data. Figure from Ryberg (2015).

Interannual variability in precipitation affects grassland productivity and non-native invasive species such as yellow sweetclover, with both responding positively to wet years (e.g., 2011) and negatively to hot, dry years (e.g., 2012, Figure 6).

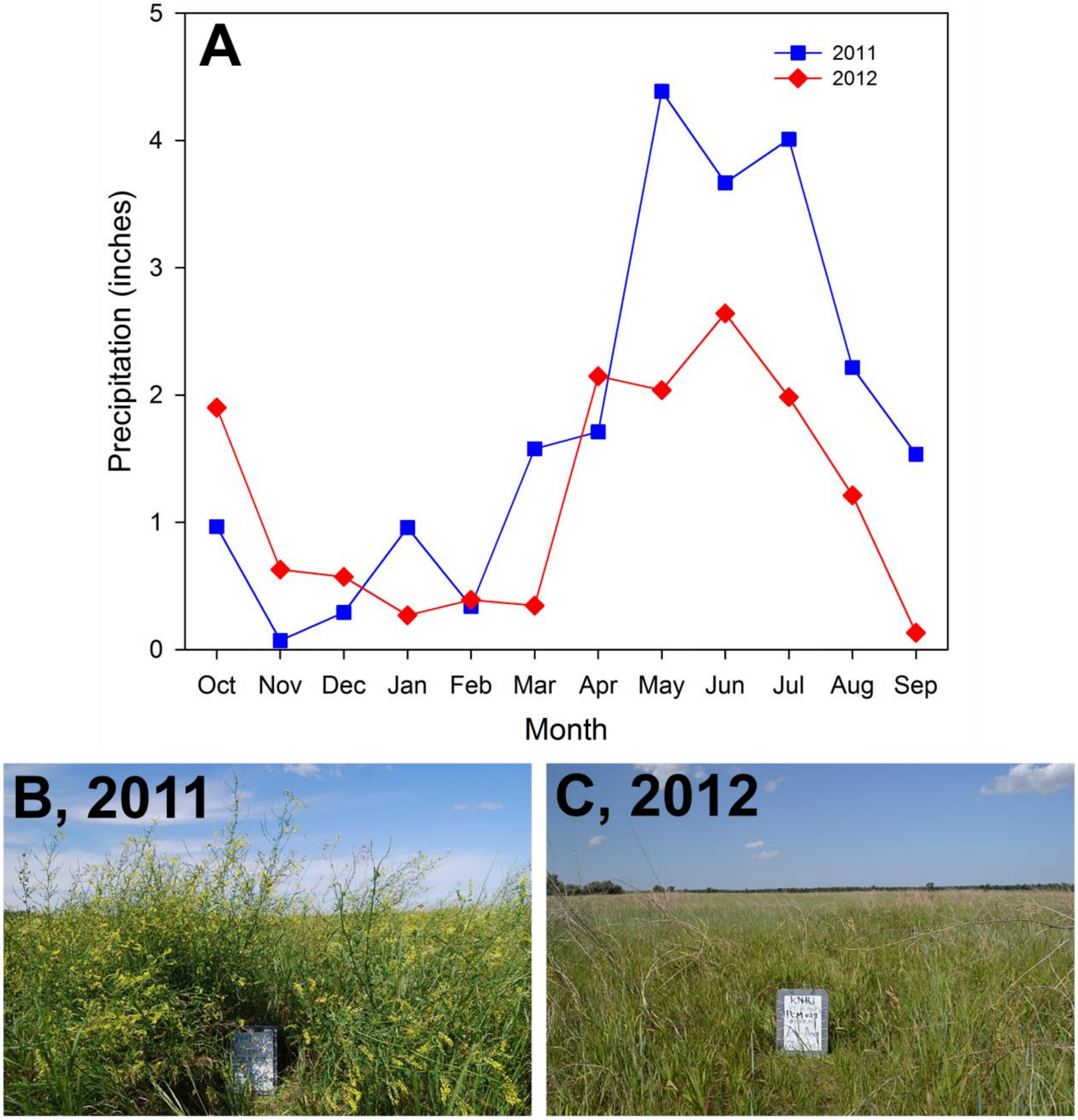


Figure 6. Interannual variability in precipitation and effects on grassland productivity and non-native species. a) Hydrologic year (Oct-Sept) precipitation for 2011 (blue boxes) and 2012 (red diamonds). b) Wet conditions in 2011 resulted in high grassland productivity and abundant non-native cover of species such as yellow sweetclover. c) Dry conditions in 2012 resulted in lower grassland productivity and sparser non-native species cover. Graph from A. Symstad; images from NPS Northern Great Plains Fire Ecology Program.

Average future climate projections for the Northern Great Plains indicate continued warming and potentially more precipitation (Figure 7; Kunkel et al. 2013).

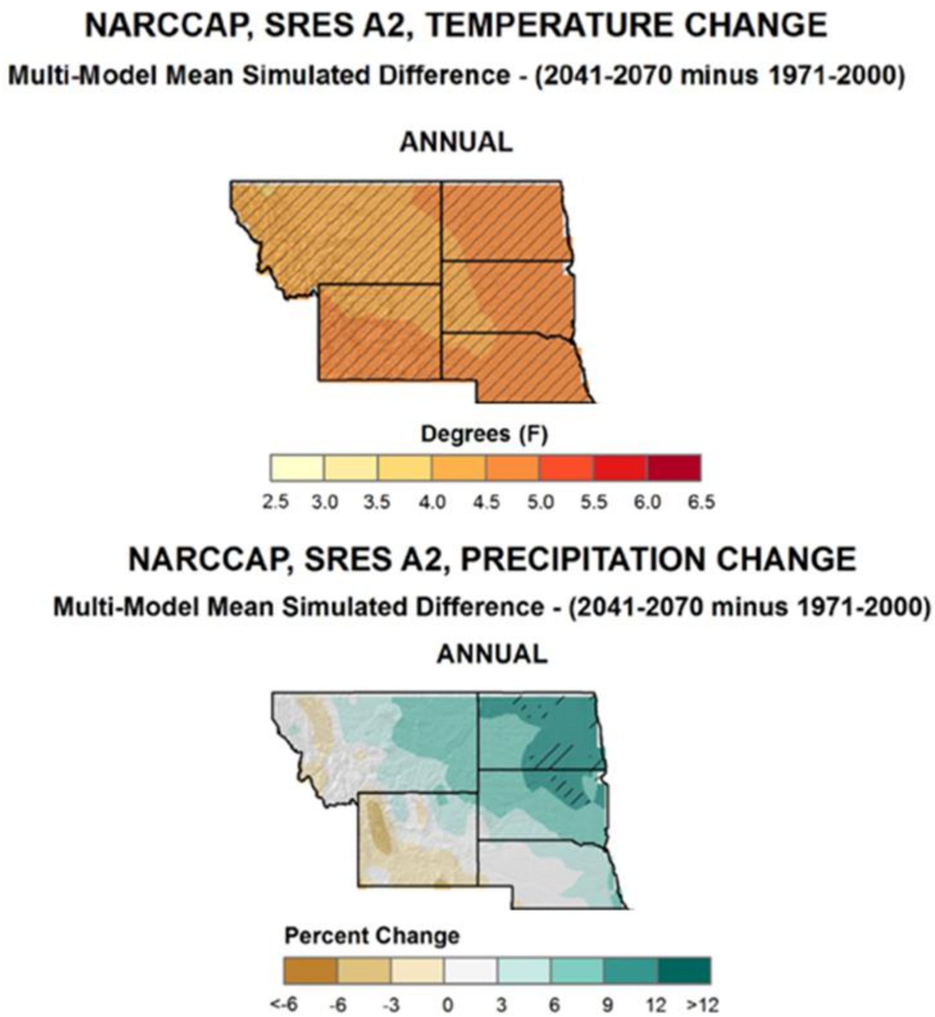


Figure 7. Projected multi-model mean annual temperature and precipitation change for the Northern Great Plains from 11 downscaled global climate model SRES A2 greenhouse gas emissions scenario projections. Color with hatching indicates >50% of the 11 models show a statistically significant change and >67% agree on the direction of change. Modified from figures 14 (top) and 25 (bottom) from Kunkel et al. (2013).

However, projections vary among individual models; climate projections for 2020-2049 summarized for the workshop span a range of warming in annual temperature from +1.3 °F to +4.5 °F, and a range of annual precipitation change from -8% to +20% (Figure 8).

Additionally, seasonal shifts in precipitation patterns (type, frequency, and intensity) and growing season conditions (onset, duration, and soil moisture levels) vary among climate models. Given the range of future projections, planning for a single future is highly unlikely to prepare a manager for what will actually transpire in the coming decades.

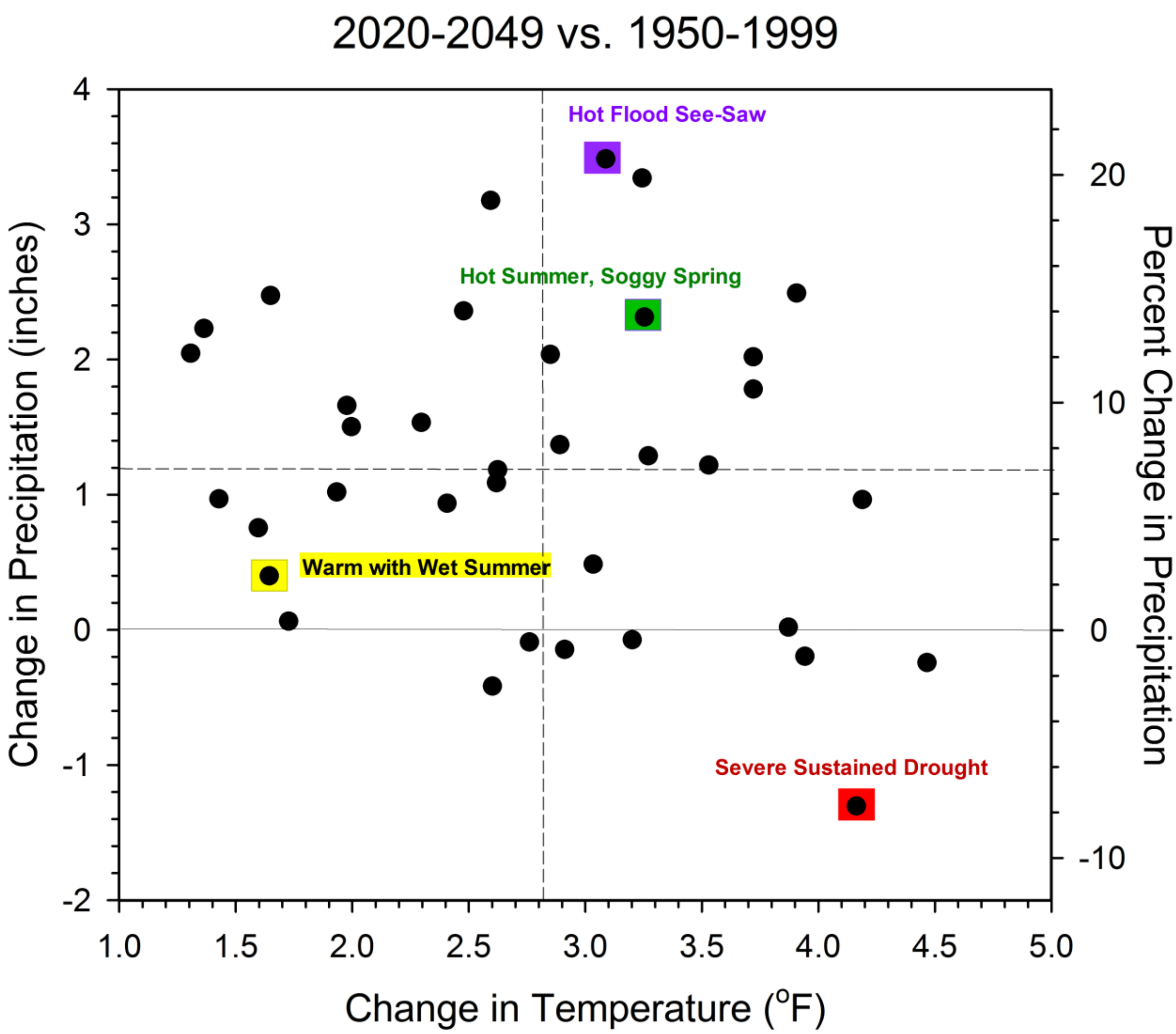


Figure 8. Annual temperature and precipitation changes from 36 downscaled CMIP3 Global Climate Model (GCM) high emissions (SRES A2) projections for Knife River Indian Villages National Historic Site, Stanton, ND (climate data from Reclamation 2013). Dashed lines indicate the median value for each axis. Symbols in filled colored boxes are projections selected for scenarios. Box fill color corresponds with scenario colors used through the rest of this document. See Appendix 1 for details on climate data and scenario selection.

Central North Dakota Climate Scenarios

We developed four climate scenarios for central North Dakota to explicitly consider the range in projections resulting from uncertainties in the models of near-term climatic conditions and potential changes to river flow (including the flood regime), growing season conditions, and ecosystem productivity. These scenarios are alternative climatic conditions represented in the projections that could play out in the coming decades (2020-2049) and are characterized by four basic qualities: plausible, challenging, relevant, and divergent (NPS 2013). The scenarios are intended to specifically challenge managers' thinking on implications for archeological sites, cultural landscapes, riparian ecosystems, and upland grasslands. Climate and hydrological data are from Reclamation (2013); see Appendix 1 for methods. We considered absolute changes and percent change compared to the historical period (1950-1999) for annual and monthly temperature, precipitation, and soil moisture, as well as annual time series of these variables. Snowpack (reported as snow water equivalent and used as a proxy for winter and spring flooding) and peak summer river flows were also considered. Scenario descriptions consisting of text, figures (9-18), and a table (1) were provided to participants at the workshop and are reproduced below.

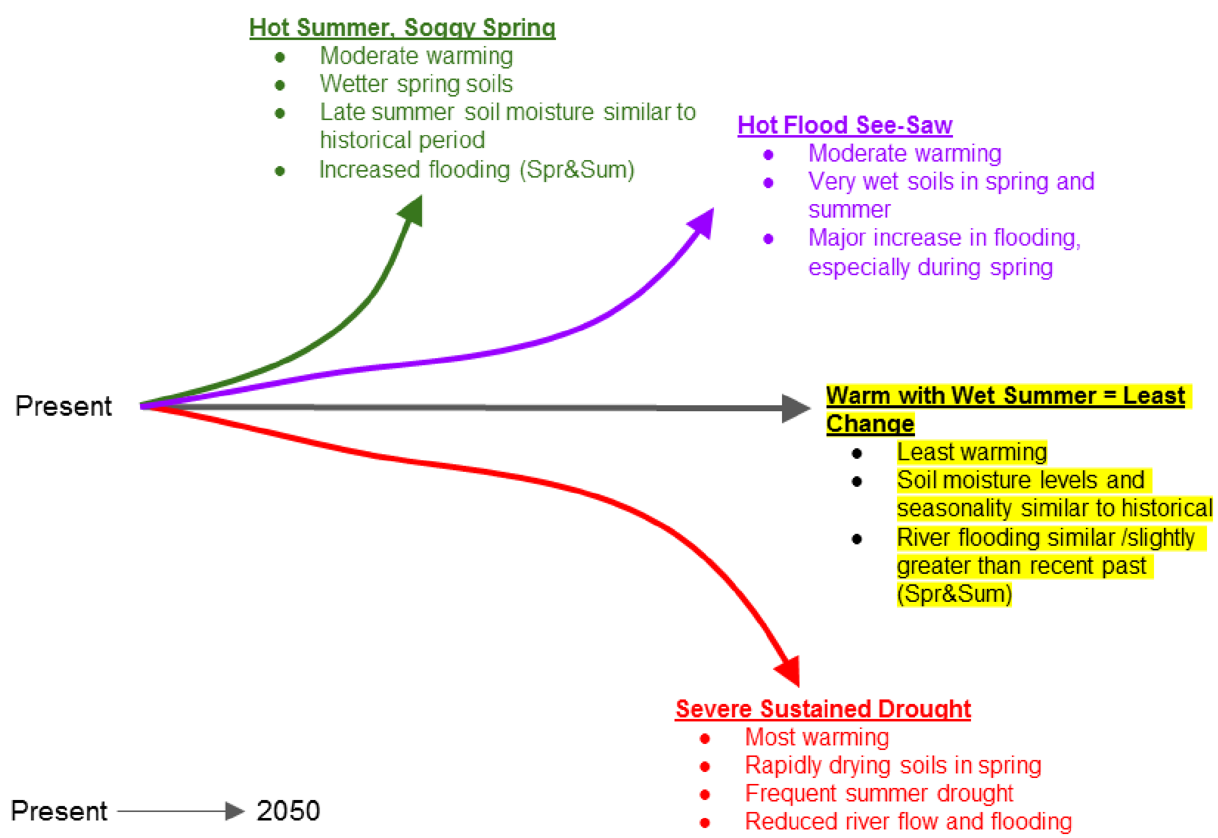


Figure 9. Key climate characteristics of each scenario for central North Dakota.

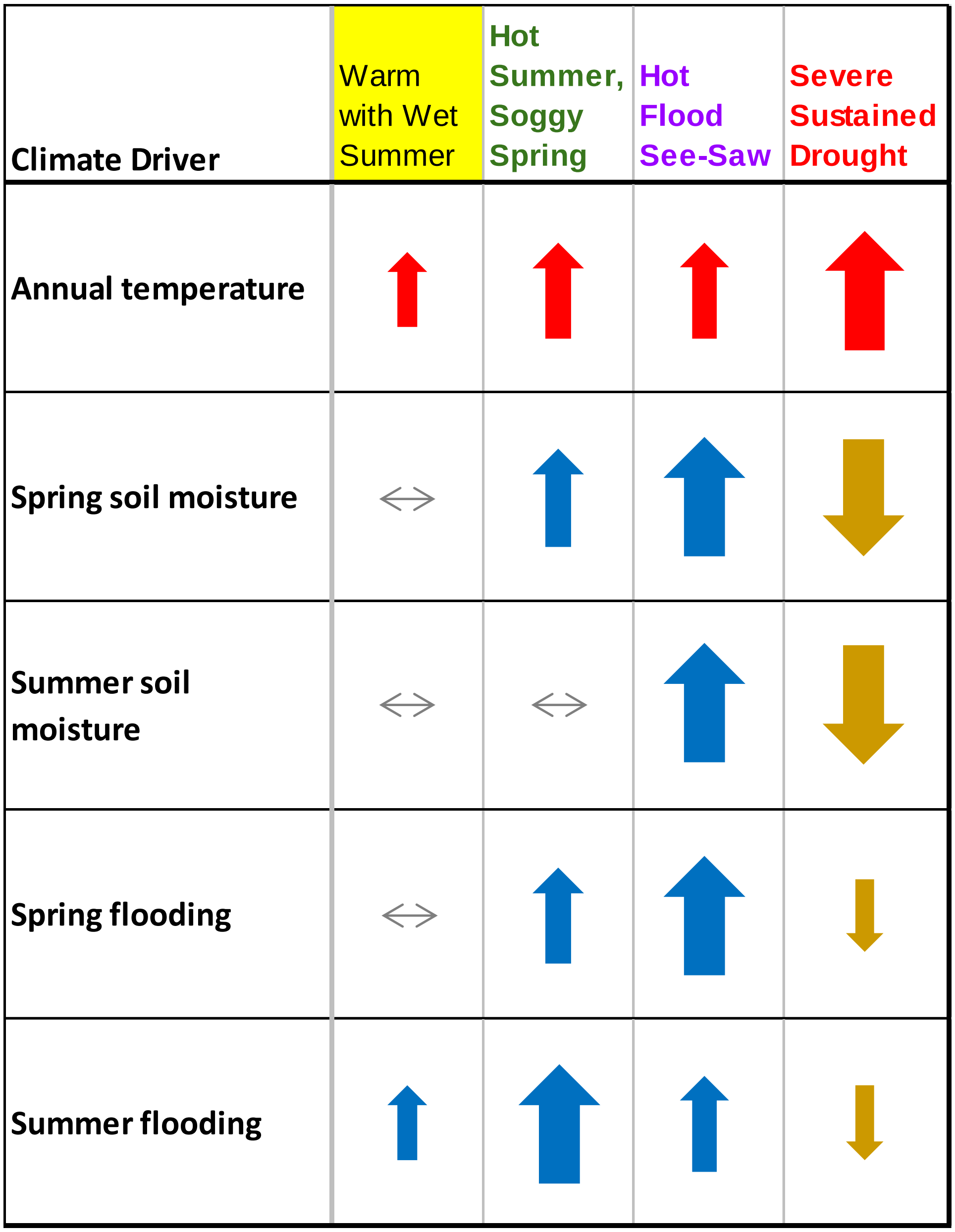


Figure 10. Climate drivers for the next 35 years (through 2050) for the central North Dakota scenarios. Arrow size and direction denote trends compared with historical conditions (1950-1999). Down arrows denote decreasing trends, up arrows increasing trends, and sideways arrows indicate little or no change from historical conditions. Arrow size denotes the magnitude of change.

"Warm with wet summer equals least change". The warming trend of the past two decades continues, but the magnitude of change is at the low end of projections for mid-century (+1.6 °F). Late spring (May-June) precipitation increases slightly, but this increase is offset by warmer temperatures, resulting in soil moistures that are similar to the recent past across all seasons. Growing season expands by about 20 days by mid-century. Average winter and summer peak flows in the Knife River are similar to the historical range of variability (1950-1999) and the river flood regime is similar to the past decade.

Table 1. Climate drivers for the next 35 years (through 2050) for the central North Dakota scenarios. Values are averages for the 30-year period 2020-2049 compared with the 1950-1990 historical period. SWE: snow water equivalent, W: winter; Sp: spring, Su: summer, Fa: fall.

Driver (2020-2049 compared with 1950-1999)	Warm with Wet Summer	Hot Summer, Soggy Spring	Hot Flood See-Saw	Severe Sustained Drought
Annual temperature	+1.6 °F	+3.2 °F	+3.1 °F	+4.2 °F
Seasonal temperature	W: +2.2 °F Sp: +1.1 °F Su: +1.6 °F Fa: +1.6 °F	W: +1.6 °F Sp: +3.0 °F Su: +5.0 °F Fa: +3.4 °F	W: +4.1 °F Sp: +1.8 °F Su: +3.8 °F Fa: +2.6 °F	W: +4.6 °F Sp: +3.8 °F Su: +4.4 °F Fa: +3.8 °F
Annual precipitation	+0.4" (+2%)	+2.3" (+12%)	+3.5" (+17%)	-1.3" (-8%)
Seasonal precipitation	W: +0.1" (+7%) Sp: +0.3" (+7%) Su: +0.4" (+4%) Fa: -0.4" (-13%)	W: +0.4" (+26%) Sp: +0.3" (+6%) Su: +0.7" (+8%) Fa: +0.9" (+22%)	W: +0.4" (+22%) Sp: +0.9" (+17%) Su: +1.4" (+14%) Fa: +0.9" (+21%)	W: +0.05" (+4%) Sp: +0.7" (+13%) Su: -1.5" (-22%) Fa: -0.6" (-21%)
Growing season length	+20 days/yr	+25 days/yr	+25 days/yr	+30 days/year
Spring soil moisture (Mar, Apr, May)	-2%	+8%	+13%	-7%
Spring soil moisture (% of years < historical)	43%	47%	33%	73%
Summer soil moisture (Jun, Jul, Aug)	+2%	+4%	+11%	-5%
Summer soil moisture (% of years < historical)	53%	53%	40%	73%
Peak Winter Snow Water Equivalent (SWE)	-9%	+20%	+47%	-13%
Summer peak flow	+17%	+78%	+46%	-11%
Snow like 1996-97 (% of years w/ max SWE 2.4” or more)	0%	10%	7%	0%
Summers like 1993 (% of years w/ summer peak daily mean flow >4500 cubic feet per second)	13%	40%	30%	10%

“Hot Summer, Soggy Spring”. Annual average temperature warms moderately in this scenario (+3 °F), with greater warming in summer (+5 °F) than winter (+1.5 °F). This scenario has higher early fall and winter precipitation and higher maximum winter snowpack than occurred historically. This increased moisture leads to higher soil moisture early in the growing season; even though summer precipitation is higher, the warm temperatures cause soils to dry out to average historical levels by late summer. Growing season expands by about 25 days by mid-century.

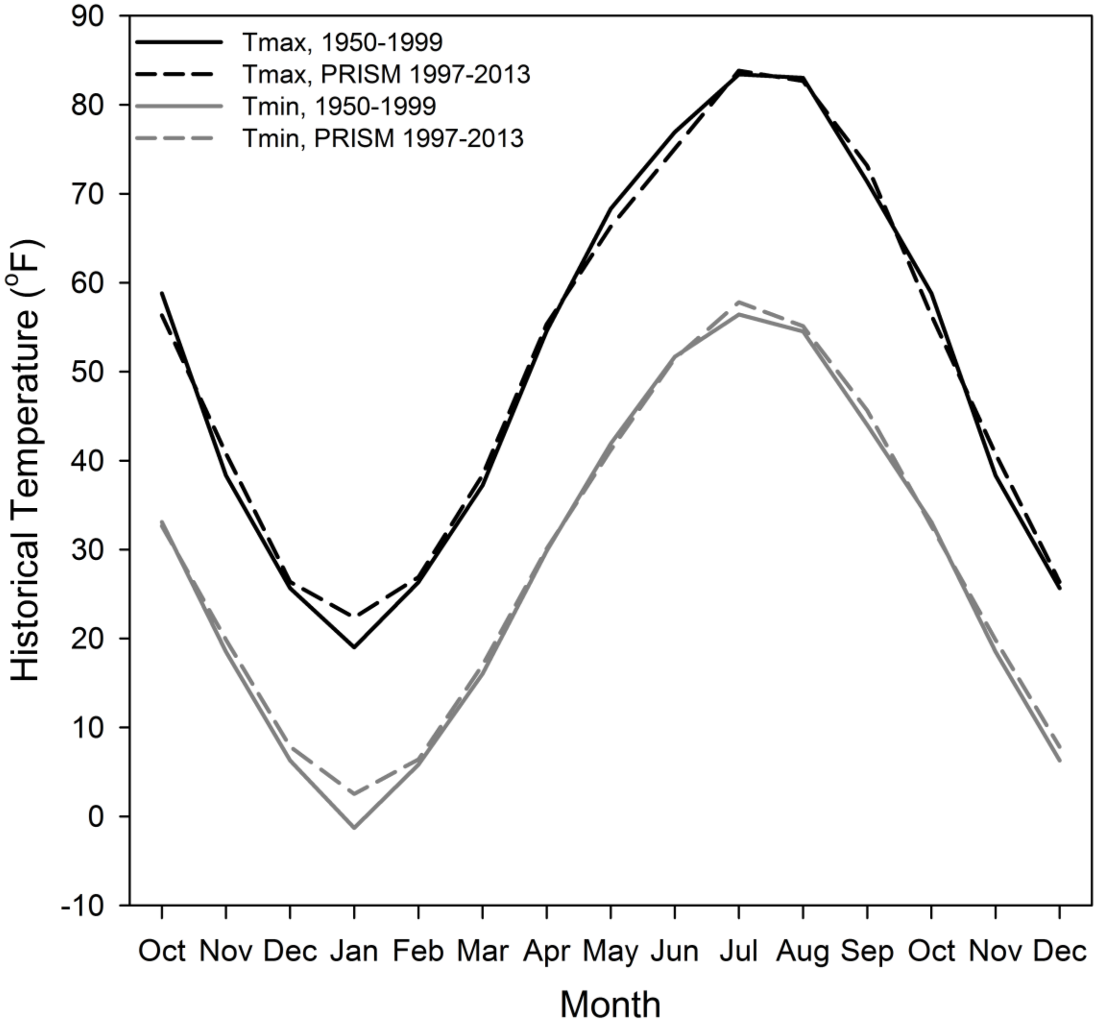


Figure 11. Historical monthly temperature. Tmax: average maximum temperature; Tmin: average minimum temperature (daily values averaged across each month); solid lines: 1950-1999 (from Maurer et al. 2002); dashed lines: 1997-2013 (from PRISM Climate Group, prism.oregonstate.edu). X-axis in this and following graphics shows October through December to represent both the water year and calendar year, and to better visualize the full cold-season.

"Hot Flood See-Saw". The moderate annual temperature increase of about 3 °F is similar to the "Hot Summer, Soggy Spring" scenario, but the seasonality of warming is flipped, with a slightly larger increase in winter than summer temperature. Increases in July and autumn precipitation, combined with smaller temperature increases in spring, keep soil moisture 5-10% higher than historical levels year-round. Both winter and summer average peak flows in the Knife River are about 50% higher than historical averages, leading to increased risk for both winter/spring flooding and summer flash flooding. Years of lower summer soil moisture are punctuated with more years of very high soil moisture than in the past. Growing season expands by about 25 days.

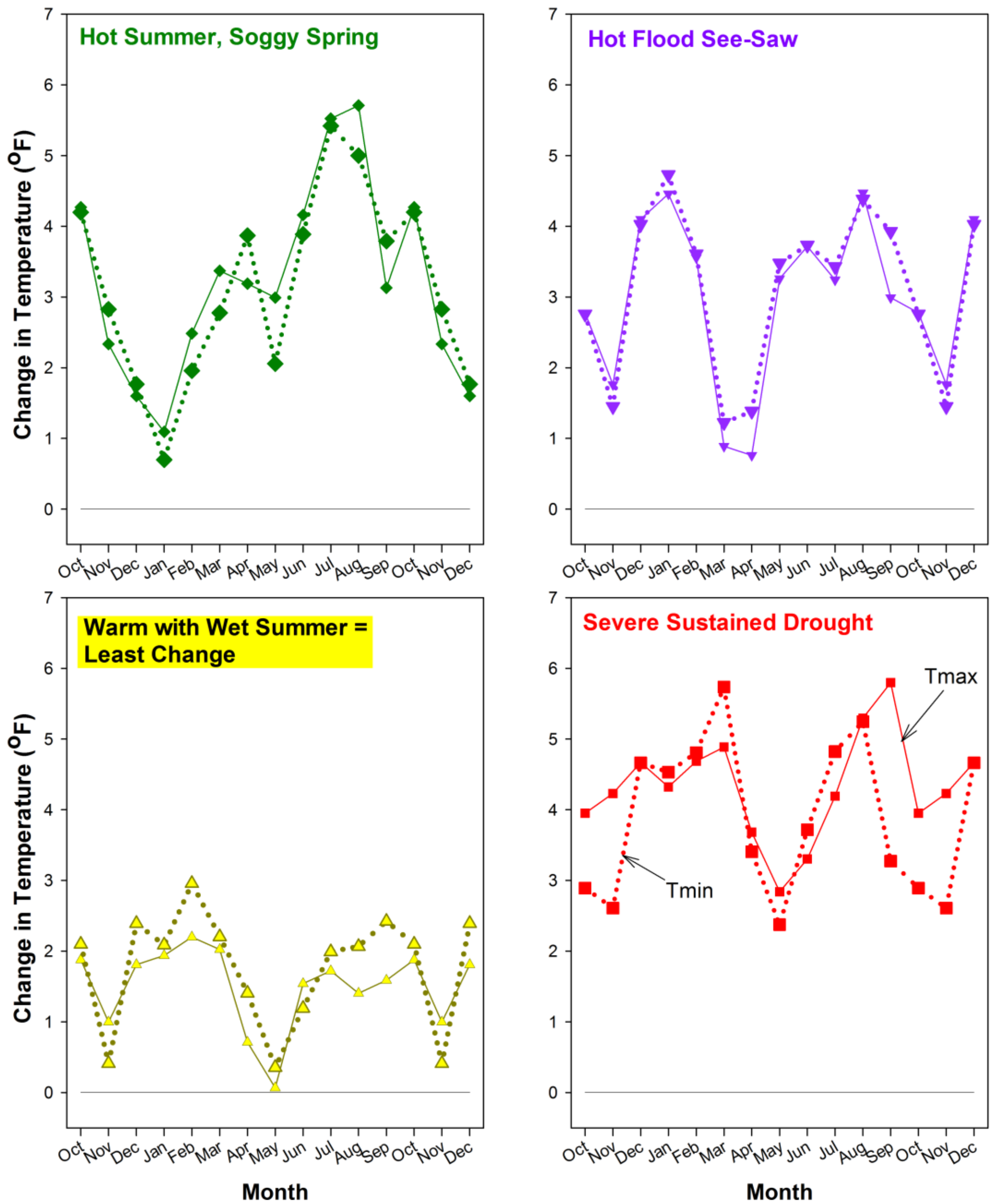


Figure 12. Scenario (2020-2049) monthly temperature departures from 1950-1999 average.

"Severe Sustained Drought". This scenario includes warming at the high end of projections (+4 °F) and a pervasive drying trend. June-August precipitation drops noticeably. This reduced summer precipitation, combined with higher temperatures, drives down soil moisture in the coming decades. Conditions similar to the recent past occur for the next decade, with soil moisture swinging from low to high from year to year as in the past, but then 5-6 years of somewhat low soil moisture are followed by a 10-year drought of very low spring and summer soil moisture. Growing season expands by about 30 days due to the strong warming, although dry conditions limit late summer vegetation productivity. Winter and summer flooding are noticeably reduced compared to the historical period.

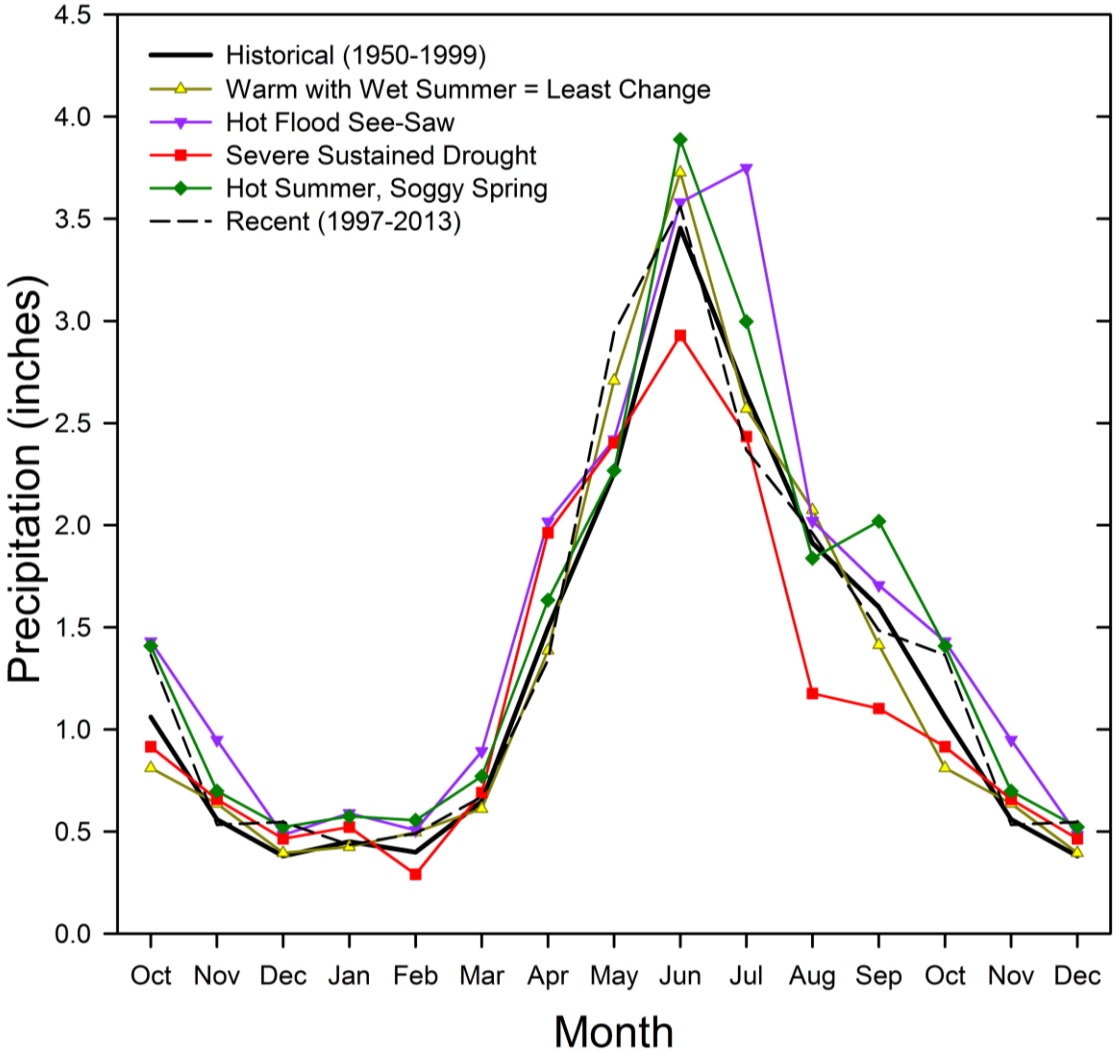


Figure 13. Long-term average monthly precipitation for historical (1950-1999, data from Maurer 2002) and recent (1997-2013, data from PRISM) periods and workshop scenarios (2020-2049).

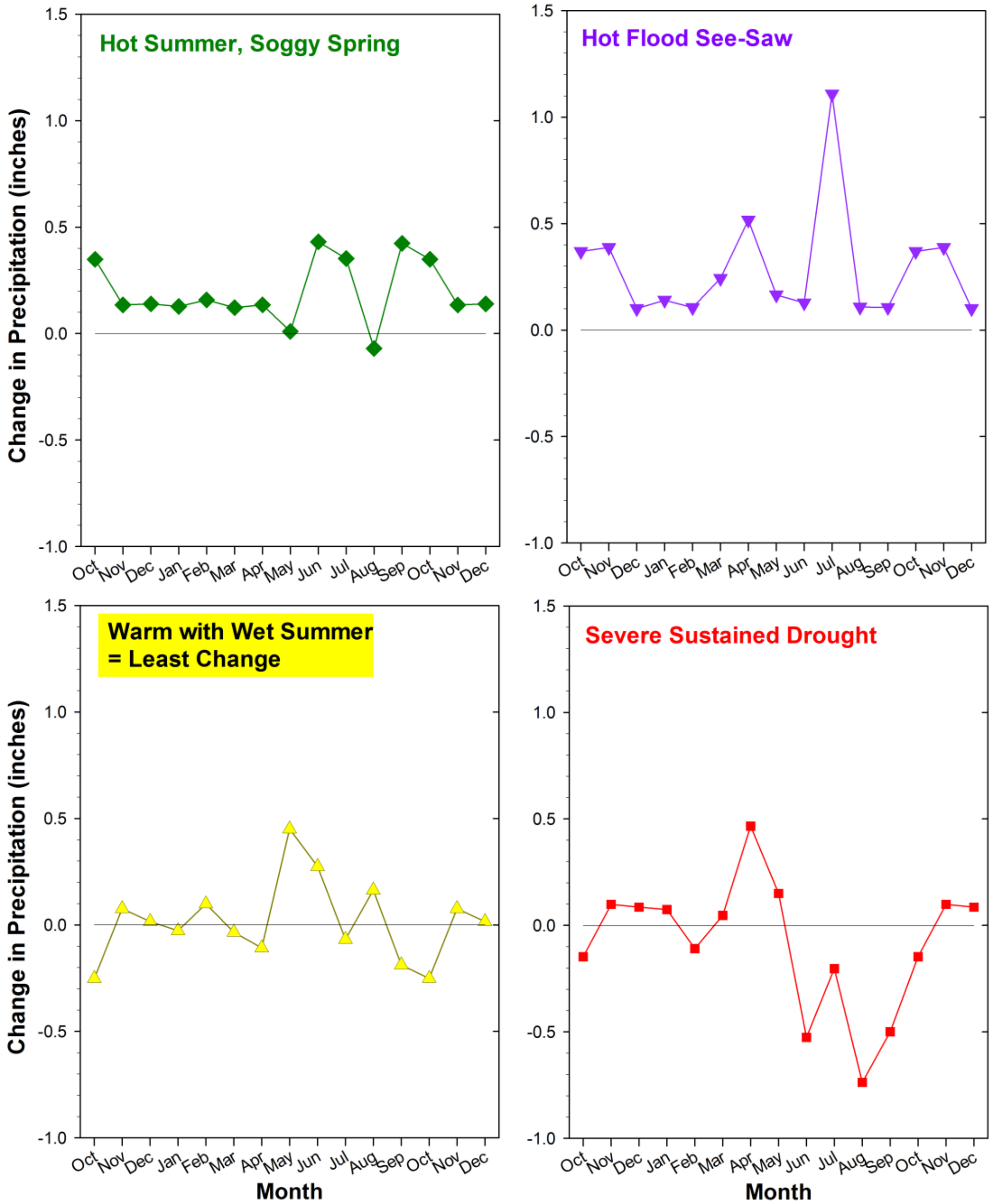


Figure 14. Scenario (2020-2049) monthly precipitation departures from 1950-1999 average.

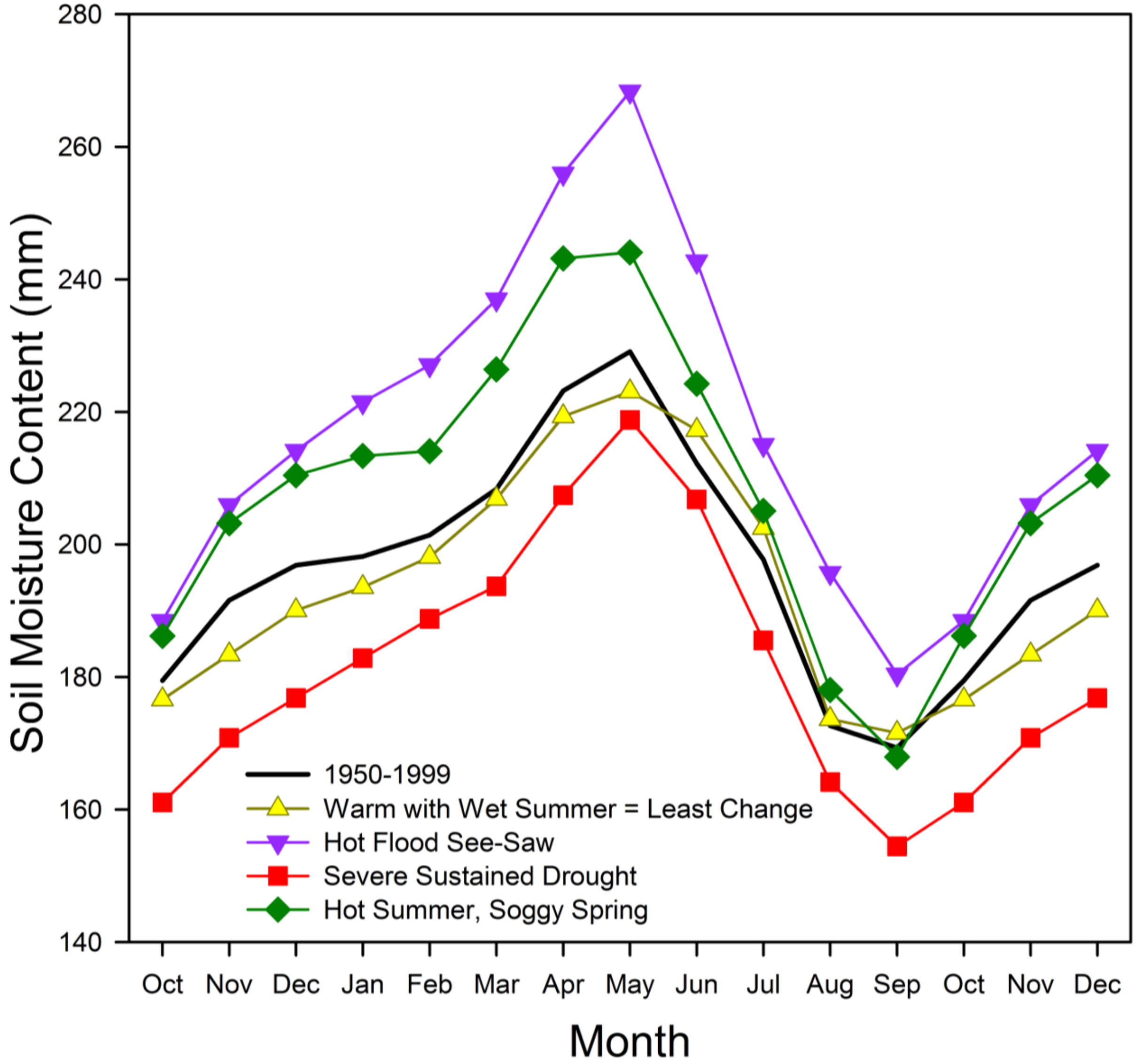


Figure 15. Long-term average monthly soil moisture. Historical (1950-1990, black line) and scenarios (2020-2049). Note that the soil moisture model output is for the first of the month.

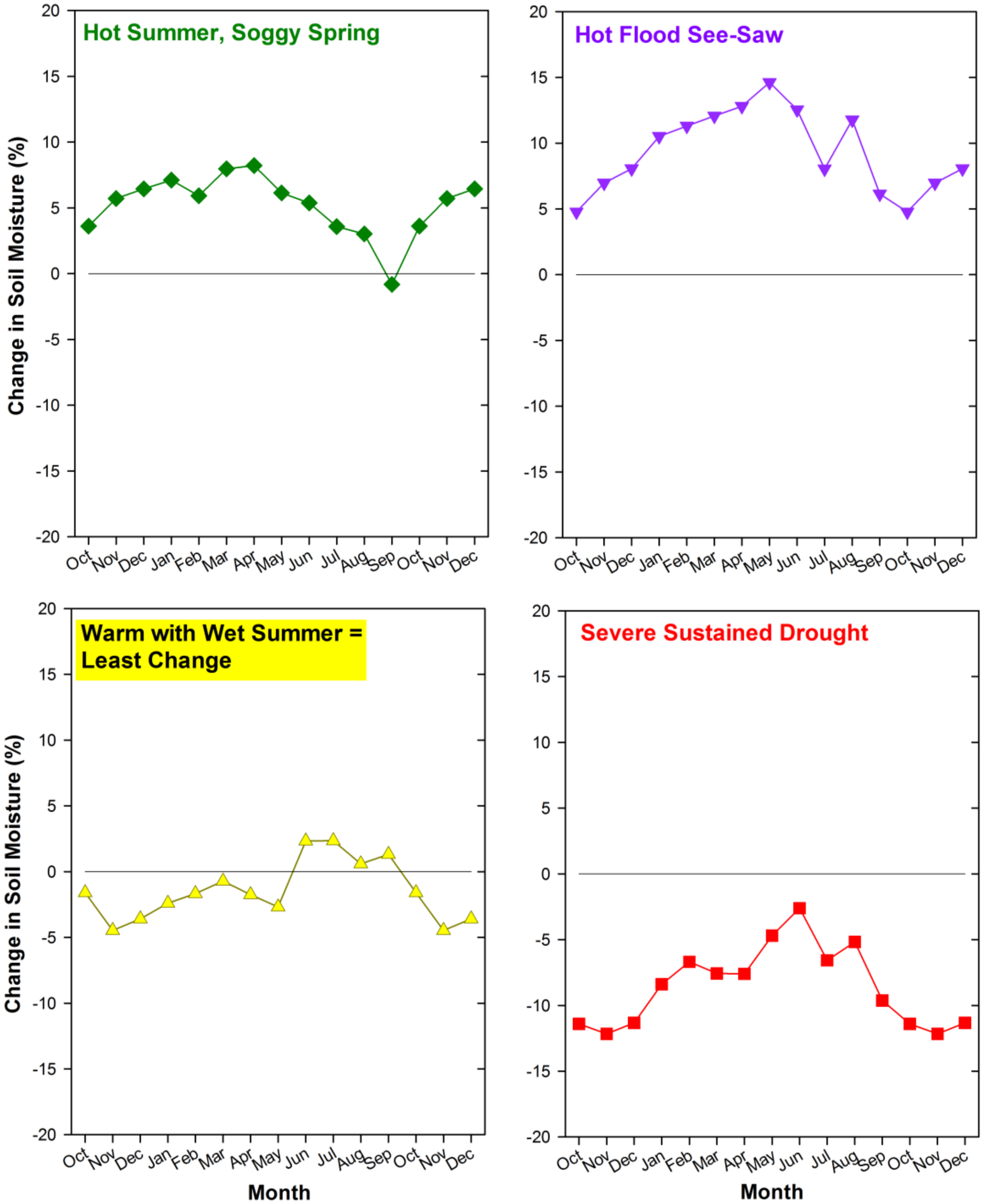


Figure 16. Scenario (2020-2049) monthly soil moisture departures from 1950-1999 average. Note that the soil moisture model output is for the first of the month.

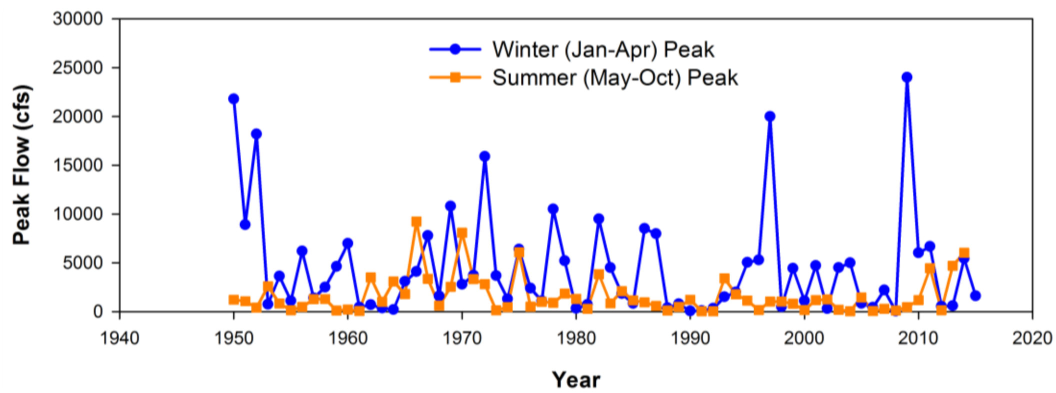


Figure 17. Historical annual winter (blue) and summer (orange) peak river flows for the Knife River, from the USGS gage at Hazen, ND.

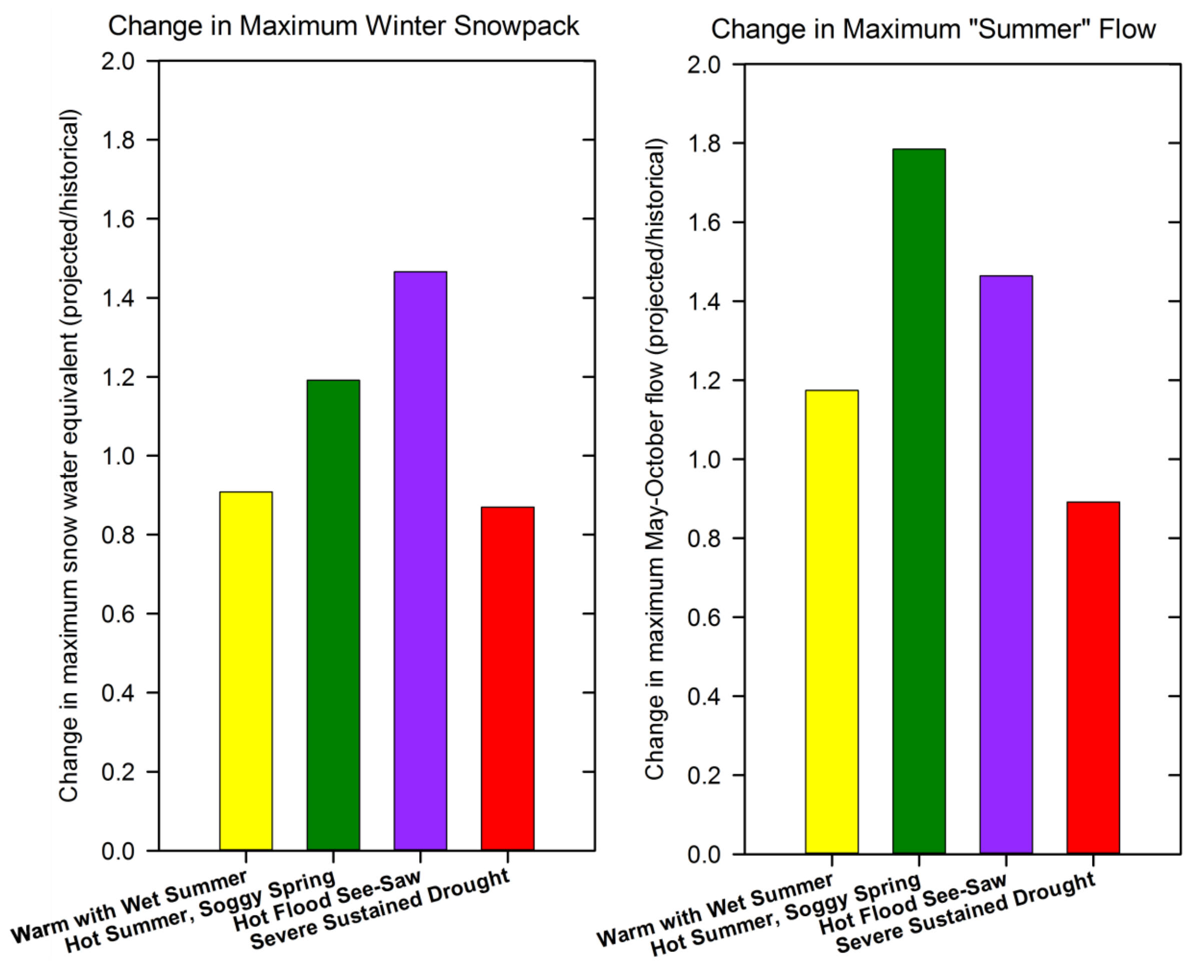


Figure 18. Ratio of scenario (2020-2049) to historical (1950-1999) average maximum winter snow water equivalent (SWE) (left) and maximum summer (May-October) river flow (right).

Scenario Implications

Workshop participants separated into groups and each group examined the implications of a single climate scenario on focal resources and potential socio-political developments (Table 2; see Appendix 2 for more details). Each workgroup included managers, scientists, and subject matter experts with different backgrounds in order to create diverse groups with broad expertise. The descriptions below are from these small-group discussions in a workshop setting and should not be taken as vetted research statements of responses to the climate scenarios, but rather as insights and examinations of possible futures based on local expert science and management knowledge (Martin et al. 2012, McBride et al. 2012). Common topics include changes in human population, agriculture, flooding impacts, and invasive species. Some developments may occur across more than one scenario; however, workgroups may have focused on different aspects of the scenarios and thus the implications vary. Some changes are more uncertain than others (e.g., changes in the abundance of pocket gophers) and indicate areas of needed future research.

Table 2. Potential scenario developments and implications

Developments and Implications	**Warm with Wet Summer = Least change**	**Hot Summer, Soggy Spring**	**Hot Flood See-Saw**	**Severe Sustained Drought**
Socio-political and other non-climate factors	• Arrival of emerald ash borer • Increased land conversion to agriculture (w/ increased drain tile) • More urbanization	• Population increase • Increase in recreation • Increased irrigation water availability/ development	• Increase in recreation • Flood damage to local communities ($$$) • Increase in agriculture	• Decreased water and increased demand / competition (urban, agriculture, industrial) • Decreased water recreation
Archeological Sites / Cultural Landscapes	• Continued episodic riverbank erosion and loss of cultural sites	• Increased river bank erosion from spring floods and strong summer storms • Increase in pocket gophers and damage to archeological sites	• Major loss of sites during frequent heavy spring floods • Other sites buried by flood sediment deposits • Loss of cache pits due to increase in soil moisture • Loss of ethnographic resources	• Loss of historic Euroamerican sites and additional prehistoric sites discovered due to more frequent fires and low water • Decreased loss of archeological sites due to reduced flooding and ice jams

Table 2 (continued). Potential scenario developments and implications

Developments and Implications	**Warm with Wet Summer = Least change**	**Hot Summer, Soggy Spring**	**Hot Flood See-Saw**	**Severe Sustained Drought**
Riparian Ecosystems	• Slow decline in cottonwoods, recruitment failure • Loss of green ash, replaced by Russian olive	• Increased cottonwood establishment but subsequent removal by floods • Early algae blooms • Increased buckthorn	• Increase in cottonwood establishment • Decrease in piping plover nesting success • Increase in waterfowl • Loss of riparian areas to agricultural fields	• Cottonwood decline, recruitment failure • Herbivores concentrate in wet areas -> increased impacts • Increase in invasive species, decline in natives
Upland Grasslands	• Warm-season grasses slightly more dominant • Increase in invasive species	• Shorter prescribed fire season • High grassland productivity • Increased restoration success (high seed germination), but more weeds too • More pheasants, waterfowl	• Warm-season grasses much more dominant • More abundant nonnative sweetclover • New invasive species (cheatgrass) • Loss of grasslands to agriculture • Decrease in upland nesting success	• Vegetation production substantially reduced More wildfires • Decrease in cool-season invasive species
Facilities / Infrastructure / Other	• Trail / road loss impacts continue	• Increased road and trail erosion • Mosquito heaven / people hell • Longer tick season • Campers flock to algae-filled lakes	• Increased road and trail erosion • Decrease in building durability (increase in moisture) • Increased repair / maintenance costs to dam structures	• Decreased hydropower • Increased upstream capture /use of water • Reduced erosion damage = less repair

Testing Decisions and Options

Climate change and other global change stressors not only challenge land managers' abilities to protect natural areas but also demand that we re-think conservation concepts, goals, and objectives in a continuously changing world (Hobbs et al. 2010, NPS AB 2012, Fisichelli et al. 2015). Climate change adaptation is, in simple terms, adjustment to changing conditions. It is, more formally, "adjustment in natural or human systems in anticipation of or response to a changing environment in a way that effectively uses beneficial opportunities or reduces negative effects" (Executive Order No. 13653, 2013). To structure adaptation thinking for protected area management, adaptation strategies can be described as a spectrum from resisting change, through accommodating change, to directing change (Figure 19, Fisichelli et al. 2016; see also Millar et al. 2007, Stein et al. 2014).

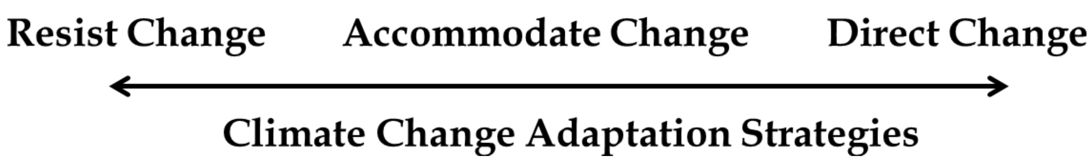


Figure 19. Climate change adaptation is about managing change and includes a spectrum of strategies from resisting to directing change. Appropriate strategies will vary across resources, space, and time. Figure adapted from Fisichelli et al. (2016).

"Resist change" strategies aim towards persistence by maintaining current or past conditions. A "directed change" strategy actively manages a resource towards new, specific desired conditions. In an "accommodate change" strategy, the target responds to climate change and management intervention supports its capacity to do so without seeking to drive the system towards a specific state. There is no single adaptation option that is appropriate in all situations; rather, the appropriate strategy will vary across resources, space, and time. For example, many persistence strategies are suitable in the near term but are likely to become increasingly risky and costly as time goes on (Millar et al. 2007). Management response to climate change therefore needs to be continuous and continually reassessed.

Scenarios provide a platform for strategic conversations. Most commonly, scenarios help teams generate ideas about what they might do or change under a new set of conditions, as well as identify indicators to monitor to detect changing conditions and adjust actions. In the context of climate change adaptation, scenarios provide the setting for examining the efficacy of a range of plausible management responses. Workshop teams examined three management topics – cottonwood forests on the Knife River, the vegetation component of cultural landscapes, and archeological sites – by considering specific management actions appropriate to the three adaptation strategies (Figure 19) in the four climate scenarios (details in Appendix 3). The descriptions below are from these small-group discussions in a workshop setting and thus should not be taken as vetted research statements of responses to the climate scenarios.

Cottonwood Forests

Drought kills riparian cottonwood trees. In addition, cottonwood regeneration requires a dynamic river system and flooding. Cottonwood regeneration is not occurring in floodplains along many dammed rivers in the western U.S. because the strongly controlled flows inhibit channel movement. Cottonwood forest management options range from resisting loss of existing forest and retaining historical dynamics; to adapting to emerging conditions and favoring cottonwood regeneration only in specific locations; to supporting conversion of cottonwood forest to other native species.

Enhanced flooding in the **Hot Summer, Soggy Spring** and **Hot Flood See-Saw** scenarios were viewed as likely to more frequently create conditions suitable for cottonwood establishment, thus making strategies to maintain cottonwood on at least some parts of the Knife River feasible under those scenarios. Under the **Severe Drought** scenario, resisting change would be very costly and the preferred option was to accommodate change by allowing cottonwoods to die and planting other native species. Across scenarios, flooding impacts to archeological resources are likely to limit management flexibility to foster cottonwoods.

Vegetation in Cultural Landscapes

For the vegetation component of cultural landscapes, resisting change means keeping all native species where they are now. Directing change has a focus of creating small areas with populations of culturally important species, potentially through intensive management intervention. Finally, accommodating change means letting the vegetation composition shift with climatic conditions while continuing to limit non-native species.

The workgroup found resisting change to be least viable under the **Severe Drought** scenario, and instead viewed directing change and creating demonstration plots of culturally important species as a practical approach under this scenario. The tools of mechanical and chemical invasive species control, prescribed fire, and mechanical thinning of woody species encroaching into grasslands were identified as necessary to resist change under the other three scenarios. For example, nonnative infestations of sweetclover are likely to increase with more frequent wet periods. Accommodating change, as a viable strategy, ultimately depends on the specific goals of the park and the response of tribal partners to changing conditions.

Archeological Sites

Archeological site management and preservation within and near riparian systems is challenged by the dynamic nature of rivers. Because archeological sites are non-renewable resources (i.e., no inherent adaptive capacity), the workgroup found it difficult to apply the resist, accommodate, or direct change framework in this context. Ultimately, though, the workgroup identified resisting change as *in situ* preservation through erosion control, directing change as proactive research archeology to maximize information gain before sites are destroyed by flood erosion, and accommodating change as reactive salvage archeology to capture information after disturbance events and acceptance of the loss of information.

In situ preservation was seen as always part of the management portfolio and the favored approach for the highest-priority sites. Directing change and accommodating change both result in the destruction or consumption of archeological resources. Reactive salvage archeology (accommodating change) is not preferred under any scenario. Proactive research archeology requires making difficult decisions about which sites to excavate and, although not a strongly preferred action, would have the greatest benefit under the **Hot Summer, Soggy Spring** and **Hot Flood See-Saw** scenarios. The workgroup identified the need to plan for variability and extremes across all scenarios.

Operationalizing Scenario Planning Outcomes

The workshop closed with some descriptions of strategies for dealing with uncertainty and approaches for using scenarios and the discussions from this workshop in future planning. Scenario-based thinking has a long history in military and business contexts and is now being increasingly applied to natural and cultural resource management to support responsive management in the face of consequential and irreducible uncertainty (Figure 20). Scenario planning offers multiple benefits, including revealing assumptions and providing insights about a system. The scenarios also provide accessible storylines that lend themselves to outreach and communication about the risks and challenges linked with management decisions. More intensive application can test whether existing plans and ideas about adaptation options remain effective across a wide range of plausible, potential futures. Where existing plans and options fall short, scenarios can be used to help develop new options. The ultimate outcome may be a portfolio of options, where the investment in specific options is anticipated to shift over time as the future plays out.

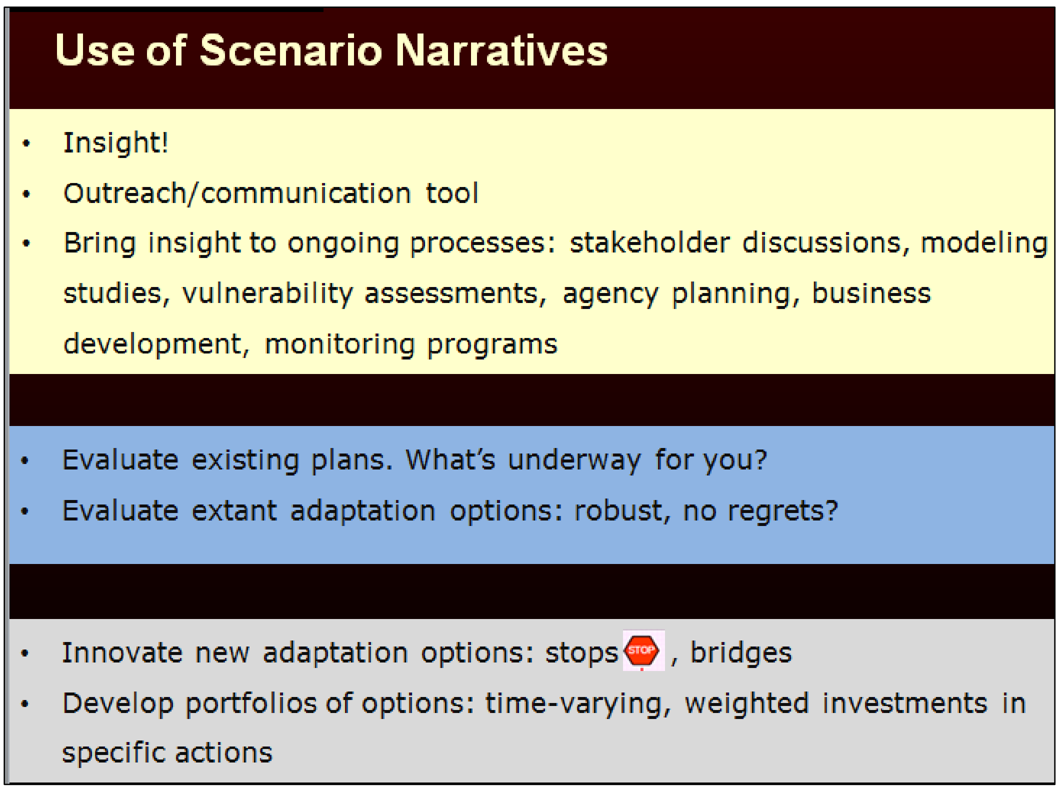


Figure 20. Well-developed scenarios in narrative form can provide insight, evaluate the future efficacy of existing plans and approaches, and drive development of new options and ultimately a suite of potential responses to an uncertain future. Figure from H. Hartmann and USFWS National Conservation Training Center.

Decision-maker responses to uncertainty range from avoidance to comprehensive consideration (Figure 21). "Putting one's head in the sand" and ignoring uncertainty is probably the least effective approach because it nearly guarantees that unanticipated conditions will occur, and "punting" – i.e., simply choosing a single future and sticking with its options – will likely lead to the same outcome. "Delay and assess" is a common strategy, but reducing uncertainty may often be time-consuming or impossible and a delayed decision is functionally the equivalent of ignoring uncertainty. "Shape the future" is the approach many managers generally focus on, but it may not be practical when critical uncertainties lie in external forces – the very situation when scenario planning is appropriate. "Commit with fallbacks" – i.e., having a Plan A, Plan B, and maybe a Plan C – is more aligned with scenario planning, but more nuanced approaches exist. Specifically, a "robust" strategy holds up under all the scenarios, but it is ultimately limiting because some scenarios require some unique actions. A "portfolio of options" is the most powerful decision strategy. It is similar to a retirement or investment portfolio, where we have diverse types of holdings, and expect to shift our resources from one type to another as our goals and situations change over time.

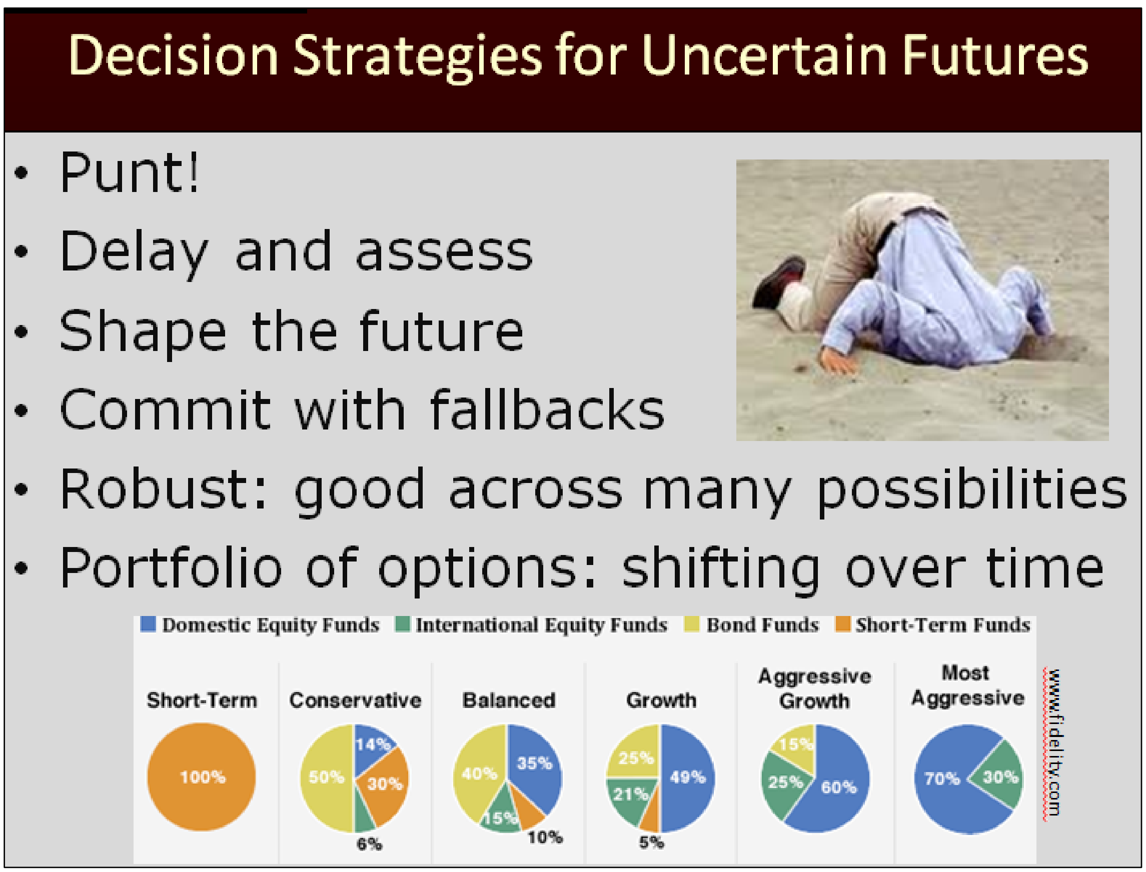


Figure 21. Responses to uncertainty range from avoidance and delay, to developing robust responses, to a portfolio of options to be used over time as the future unfolds. Figure from H. Hartmann and USFWS National Conservation Training Center.

One important point to keep in mind is the importance of defining management objectives as specifically as possible while building in flexibility and understanding the circumstances under which these might change through time (Caves et al. 2013). Different objectives have different sensitivities to climate change. For example, current objectives, such as ensuring persistence of historically occurring species, may be achievable in the near-term. However, as conditions become unsuitable, shifting to long-term objectives focused more broadly on function, such as productive vegetation, may be more feasible (Figure 22, Caves et al. 2013). Anticipating how objectives might need to shift and communicating this to stakeholders in advance is an important opportunity that can result from scenario planning.

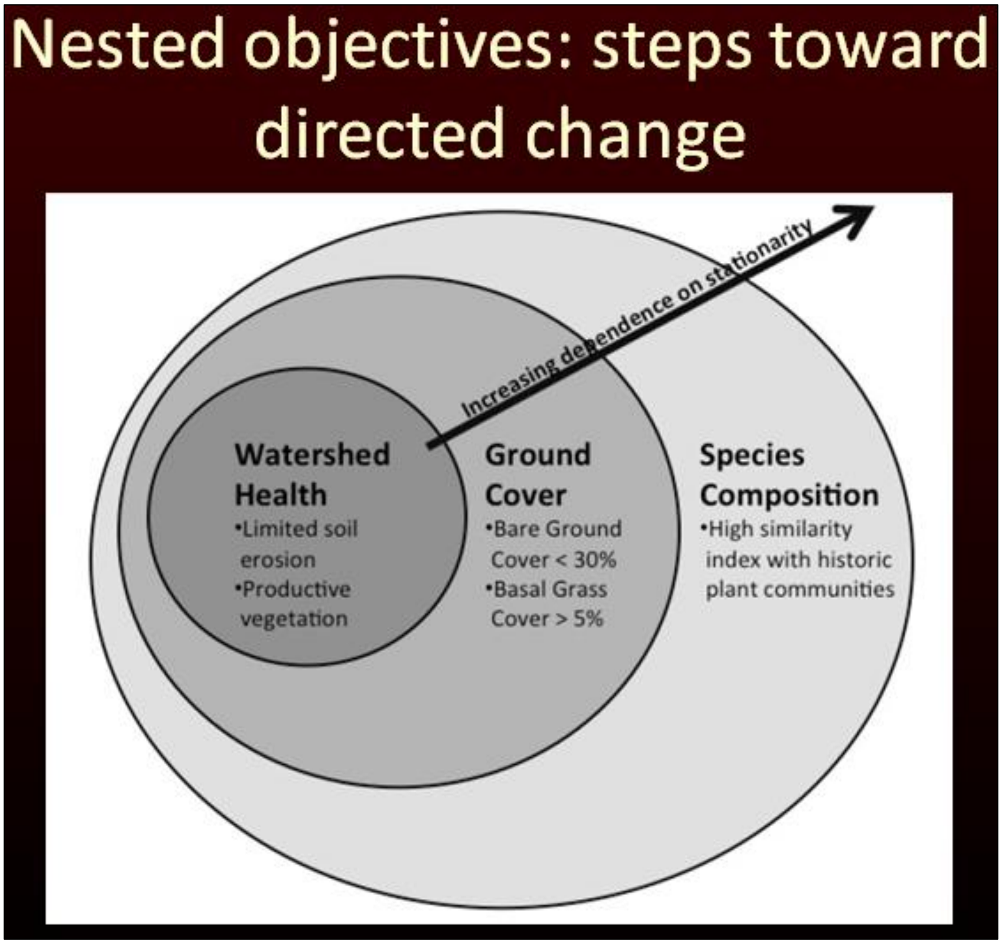


Figure 22. Defining objectives as specifically as possible is important in scenario planning because different levels of objectives have differing climate change sensitivities. Figure from H. Hartmann and USFWS National Conservation Training Center, adapted from Caves et al. (2013).

Moving forward beyond the workshop, we recommend working with a portfolio of options, matching them with corresponding potential futures, and establishing a framework for their application (see Figure 23 for three methods, H. Hartmann, personal communication). Simple time-based decision trees can identify what options to pursue in the near future, and what options to add in the future at key decision points, based on indicators. Evaluating and categorizing options as ‘no regrets’ and ‘hard’ choices can help prompt adaptation. ‘No regrets’ options confer numerous benefits (e.g., control invasive species) and implementation may be widely supported. 'Hard choice' options may be more controversial, difficult to implement, and should be considered carefully. Further breaking down 'hard choice' options may reveal some 'no regrets' components that can be more easily carried out (H. Hartmann, personal communication). Disaggregating steps and laying them out in a decision tree sets up a strong framework to operationalize management options in response to persistent uncertainty.

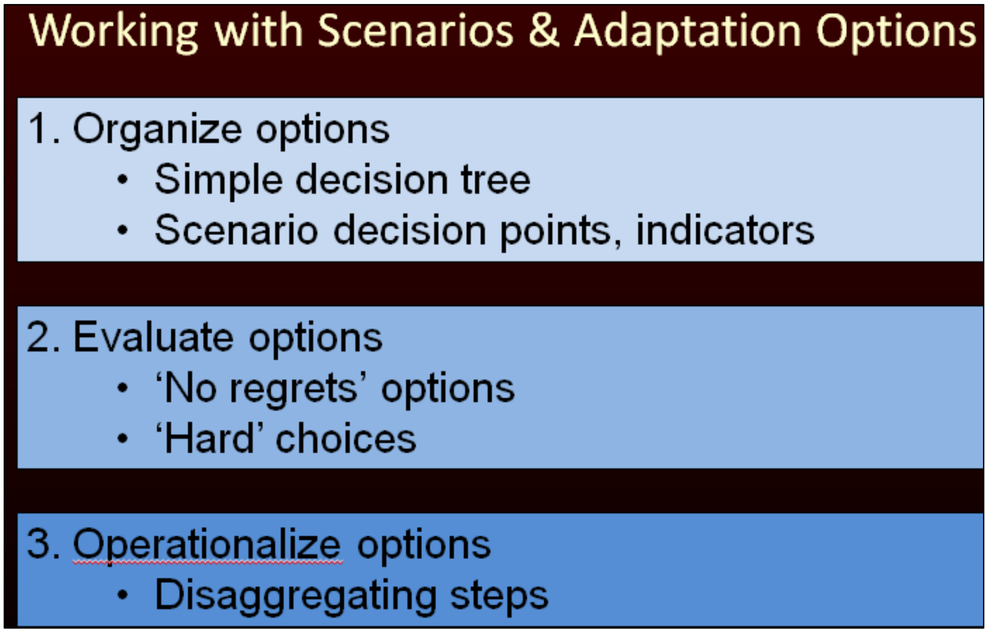


Figure 23. Disaggregating a portfolio of options into a temporal decision tree with key decision points and indicators helps operationalize adaptation. Figure from H. Hartmann and USFWS National Conservation Training Center.

Beyond improving climate literacy and understanding of ongoing changes and future uncertainties, on-the-ground application of the scenarios is the next step in the adaptation process. For example, this project is informing riverbank erosion monitoring, archeological management planning, and cottonwood riparian forest restoration efforts. These projects are in early phases; details are not available and are beyond the scope of this report.

Adaptation is an iterative process (Stein et al. 2014). These scenarios and subsequent adaptation practices should be revisited by collaborative teams of managers, planners, scientists, and adaptation specialists.

Literature Cited

Caves J.K., Bodner G.S., Simms K., Fisher L.A. and Robertson T. 2013. Integrating collaboration, adaptive management, and scenario-planning: experiences at Las Cienegas National Conservation Area. Ecology and Society 18:43.

Executive Office of the President (2013) Executive Order 13653: Preparing the United States for the 1224 impacts of climate change, November 1, 2013, 78 Federal Register 66817.

Fisichelli N.A., Schuurman G., and Sharron E. 2015. Climate change: responding to the crisis portended by George Perkins Marsh. George Wright Forum 32:276-289.

Fisichelli N.A., Schuurman G.W., and Hawkins Hoffman C. 2016. Is 'Resilience' Maladaptive? Towards an Accurate Lexicon for Climate Change Adaptation. Environmental Management 57:753-758.

Gregory R., Failing L., Harstone M., Long G., McDaniels T., and Ohlson D. 2012. Structured decision making: a practical guide to environmental management choices. John Wiley & Sons, Oxford, UK.

Hobbs R.J., Cole D.N., Yung L., Zavaleta E.S., Aplet G.H., Chapin F.S. III, Landres P.B., Parsons D.J., Stephenson N.L., and White P.S. 2010. Guiding concepts for park and wilderness stewardship in an era of global environmental change. Frontiers in Ecology and the Environment 8:483–490.

Kunkel K.E., Stevens L.E., Stevens S.E., Sun L., Janssen E., Wuebbles D., Kruk M.C., Thomas D.P., Shilski M.D., Umphlett N.A., Hubbard K.G., Robbins K., Romolo L., Akuz A., Pathak T.B., Bergantino T.R., and Dobson J.G. 2013. Climate of the U.S.—Great Plains, National Oceanic and Atmospheric Administration Technical Report NESDIS 142–144, accessed September 16, 2014 at http://www.hprcc.unl.edu/publications/files/NOAA_NESDIS_Tech_Report_142-4-Climate_of_the_U.S.%20Great_Plains.pdf.

Martin T.G., Burgman M.A., Fidler F., Kuhnert P.M., Low-Choy S., McBride M. and Mengersen K. 2012. Eliciting expert knowledge in conservation science. Conservation Biology, 26:29-38.

Maurer E.P., Wood A.W., Adam J.C., Lettenmaier D.P. and Nijssen B., 2002. A long-term hydrologically based dataset of land surface fluxes and states for the conterminous United States. Journal of Climate, 15:3237-3251.

McBride M.F., Fidler F. and Burgman M.A., 2012. Evaluating the accuracy and calibration of expert predictions under uncertainty: predicting the outcomes of ecological research. Diversity and Distributions, 18(8), pp.782-794.

Millar C.I., Stephenson N.L., Stephens S.L. 2007. Climate change and forests of the future: managing in the face of uncertainty. Ecol Appl 17:2145–2151.

National Park Service, 2013. Using Scenarios to Explore Climate Change: A Handbook for Practitioners. National Park Service Climate Change Response Program. Fort Collins, Colorado.

National Park System Advisory Board (NPS AB). 2012. Revisiting Leopold: resource stewardship in the national parks. Washington, DC. Available: http://www.nps.gov/calltoaction/PDF/LeopoldReport_2012.pdf. Accessed 2014 May.

Peterson G. D., Cumming G.S., and Carpenter S.R. 2003. Scenario planning: a tool for conservation in an uncertain world. Conservation Biology 17:358-366.

Pierce D.W., Barnett T.P., Santer B.D., and Gleckler P.J. 2009. Selecting global climate models for regional climate change studies. PNAS 106:218441-8446doi:10.1073/pnas.0900094106

PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu

Reclamation. 2013. 'Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections: Release of Downscaled CMIP5 Climate Projections, Comparison with preceding Information, and Summary of User Needs', prepared by the U.S. Department of the Interior, Bureau of Reclamation, Technical Services Center, Denver, Colorado. 47pp. Data downloaded from http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html#Welcome 22 October 2015.

Rowland E., Cross M., and Hartmann H. 2014. Considering Multiple Futures: Scenario Planning To Address Uncertainty in Natural Resource Conservation. U.S. Fish & Wildlife Service. Available at: http://www.fws.gov/home/climatechange/pdf/Scenario-Planning-Report.pdf

Ryberg, K.R. 2015. The impact of climate variability on streamflow and water quality in the North Central United States: Fargo, North Dakota State University, Ph.D. dissertation, 277 p.

Stein B.A., Glick P., Edelson N.A., and Staudt A. 2014. Climate-Smart Conservation, Putting Adaptation Principles into Practice. National Wildlife Federation, Washington, DC. Available at: http://www.nwf.org/pdf/Climate-Smart-Conservation/NWF-Climate-Smart-Conservation_5-08-14.pdf

Appendix 1. Climate Scenario Methods

The scenario creation process began with using the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset. That climate output is the basis for the bias-corrected and spatially disaggregated (BCSD) statistically downscaled product originally developed for the U.S. Bureau of Reclamation. This product was further processed through the Variable Infiltration Capacity (VIC) hydrology model to create hydroclimate variables such as soil moisture and snow water equivalent. (Reclamation 2013; http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/). These data are downscaled to a ⅛ degree (~12km or 7.5 miles) grid. A cell centered at -101.4375° longitude, 47.3125° latitude was chosen to represent central ND (this grid cell includes the Knife River Indian Villages NHS visitor center). We used 36 CMIP3 A2 emissions scenario model runs from 18 different global climate models (GCMs) from the BCSD-VIC hydrology dataset.

We divided the projections into 4 quadrants based on median annual average temperature and percent change in annual precipitation (dashed lines in Figures 8 and A1). In each quadrant, we selected 4-6 projections divergent from the ensemble average (the models indicated by squares in Figure A1) and termed them “dry” (precipitation change < 25th percentile), “wet” (precipitation change > 75th percentile), “warm” (temperature change <25th percentile), or “hot” (temperature change > 75th percentile).

For these selected projections we analyzed the downscaled data for differences between the 1950-1999 historical period and a 2020-2049 planning period. We considered absolute changes and percent change compared to the historical period for annual and monthly temperature, precipitation, and soil moisture, as well as annual time series of these variables. Snowpack and peak summer flows were also considered.

The principal threat to archaeological resources at Knife River Indian Villages is erosion in floods that occur in summer or winter. Therefore, we analyzed changes in magnitude of the annual peak flow in winter (January-April) and summer (May-October) for the Knife River using output of the Bureau of Reclamation’s VIC hydrology model driven by predicted temperature and precipitation from the projections. In backcasting mode, the VIC output matched historical flows (1950-1999) in summer, but had no skill in predicting winter peaks in this small watershed. Therefore, we used annual peak snow water equivalent (SWE) from VIC as a surrogate for peak winter flows. Because SWE output from CMIP3 matched actual snow measurements (1950-1999) and winter peak flows much better than output from CMIP5, we used the CMIP3 SWE output to explore changes in annual winter peak flows under the different climate scenarios.

We visually inspected the graphics (including Figures 11-18) and chose four projections based on the characteristics of these variables that “push the envelope”, or pose relevant challenges for management. These were severe sustained drought (**“Severe Sustained Drought”**; Model for Interdisciplinary Research On Climate, University of Tokyo, version 3.2 medium resolution, run 1; miroc3_2_medres.1, #14 in Figure A1), a scenario with both increased winter/spring flooding and summer flash flooding (**”Hot Flood See-Saw”**; Canadian Climate Model version 3.1, run 2;

ccma_cgcm3_1.2, #3 in Figure A1), and a scenario with more winter warming than summer warming ("**Hot Summer, Soggy Spring"**; National Center for Atmospheric Research, Community Climate System Model 3.0 run 2; ncar_ccsm3_0.2, #29 in Figure A1). One scenario represents the impacts of higher temperatures cancelling out wetter (higher precipitation) summers in terms of soil moisture **("Warm with wet summer equals least change"**; Meteorological Research Institute. Japan, Coupled Global Climate Model, version 2.3.2a, run 1; mri_cgcm2_3_2a.1, #23 in Figure A1). Two of the projections chosen (#s 3 and 29) are relatively close to each other in annual temperature and precipitation space (Figure A1), but they were chosen not only based on their annual characteristics, but for the seasonal cycle and time series compared to the recent past (Figures 11-18).

Pierce et al (2009) discussed the number of GCM projections required to derive estimates of regional climate change, and found that 14 projections from five GCMs was enough to represent a full set of the 21 CMIP3 model results. So, in this project, the 36 projections from 18 GCMs is more than sufficient to represent the full spread of the models. The four GCMs we selected are a subset intentionally selected to represent the spread, or divergence, of management-relevant variables within this larger spread.

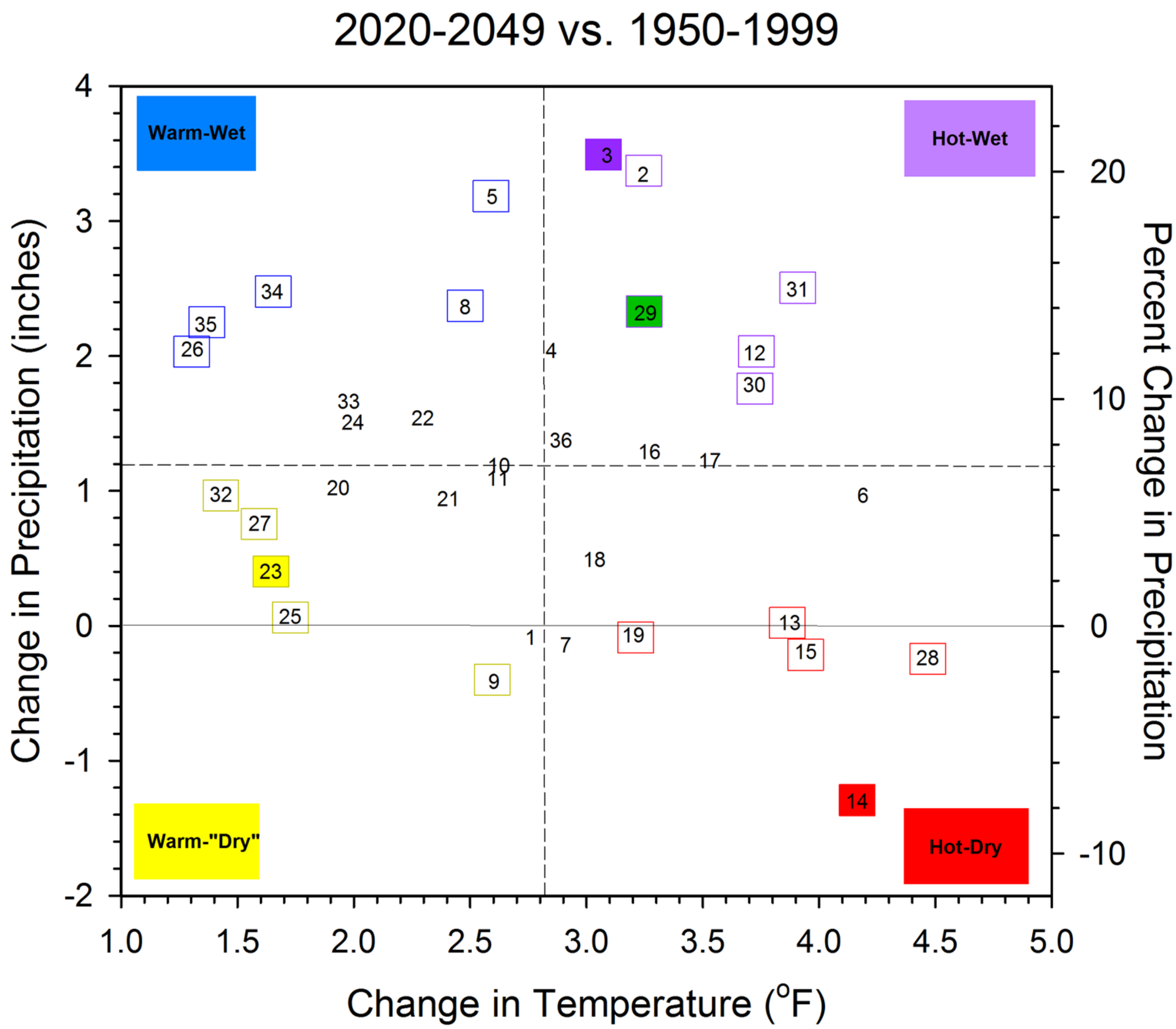


Figure A1. Annual temperature and precipitation changes from 36 downscaled CMIP3 Global Climate Model (GCM) high emissions (SRES A2) projections for Knife River Indian Villages National Historic Site, Stanton, ND (climate data from Reclamation 2013). Numbers in filled colored boxes are projections selected for scenarios from projections (in open and closed boxes) divergent from the ensemble average. Colors of these selected projections correspond with scenario colors used throughout the document). The specific projections chosen for scenarios are #3, ccma_cgcm3_1.2 (the Canadian Climate Model version 3.1, run 2); #14, miroc3_2_medres.1 (Model for Interdisciplinary Research On Climate, University of Tokyo, version 3.2 medium resolution, run 1); #29, ncar_ccsm3_0.2 (National Center for Atmospheric Research, Community Climate System Model 3.0 run 2; and #23, mri_cgcm2_3_2a.1 (Meteorological Research Institute. Japan, Coupled Global Climate Model, version 2.3.2a, run 1).).

Appendix 2. Workgroup Scenario Storyline and Impacts Worksheets

In some cases, workgroups developed alternative names for a scenario (name in parentheses on the worksheet if recorded by the group). This appendix is provided so that participants of the workshop can review their workgroup exercises and to provide ideas for others wishing to use scenario planning.

ND Scenarios: 2015-2050______ Warm with wet summer = Least Change________________

In your scenario:

Regional Climate Features:
• Slightly warmer • Slightly wetter summer • 20+ more days to growing season • Historical flood regime
What socio-political developments might occur alongside the climate changes?
• Arrival of emerald ash borer (EAB) • Increased land conversion to agriculture • Increased drain tile in fields • Urbanization • Increased runoff

What Happens to:

Archeological / Cultural landscapes	Riparian ecosystems
• Continued riverbank erosion and loss of archeological sites and cultural landscapes	• Slow decline in cottonwoods due to recruitment failure • Loss of green ash (EAB), replaced by Russian olive • Increased bird clutch size • Decreased fish kill in winter
Upland Grasslands	Facilities / Infrastructure
• Mild shift to warm season grasses • Increase in invasive species (thistle, clover, Kentucky bluegrass, and new species)	• Trail / road loss impacts continue • Increased clover resulting in increased bees • Increased carbon sequestration • Water used for energy

ND Scenarios: 2015-2050______Hot Summer, Soggy Spring_(ND++)____

In your scenario:

Regional Climate Features:
• Increased summer and winter temperatures • Wetter May-June and fall • Heavier snowpack • Growing season approximately 25 days longer • Soil moisture increase except early fall • Severe storms (bigger) • Earlier (& longer) severe storm season • Exaggerated seasonal cycle
What socio-political developments might occur alongside the climate changes?
• Increased regional population • Increased irrigation water availability / development

What Happens to:

Archeological / Cultural landscapes	Riparian ecosystems
• Increased bank erosion from increased precipitation, increased flood magnitude and frequency and ice scour. • More winter spring floods • Increase in pocket gopher therefore increase in archeological disturbance to archeological sites	• More winter spring floods • Even more summer floods • Cottonwood regeneration wiped out regularly • Early algae blooms • Increased buckthorn
Upland Grasslands	Facilities / Infrastructure
• Prescribed fire season shorter, pushed earlier and later (hard to burn in spring) • increased wildfire (late summer) risk • clover and thistle expand • lusher vegetation and waterfowl / pheasants all around • increased seed germination (restoration) but more weeds too • shorter planting timeframe	• Increased trail erosion • Fall harvest difficult in many years due to wet conditions • Corn maturing problems • Increased road erosion and maintenance needs • Mosquito heaven / people hell • Longer tick season • Campers flock to algae-filled lakes • Potential increased spring wheat productivity

ND Scenarios: 2015-2050______Hot Flood See-saw____________________

In your scenario:

Regional Climate Features:
• Temperatures rise (+3 degree rise in annual temp and especially strong rise in winter) • 5-10 % increase in soil moisture • 17% increase in rainfall • 25 more growing days • 50% higher peak flows –Knife River – increased flash flooding
What socio-political developments might occur alongside the climate changes?
• Increase in visitation (winter months) • Flood damage to local communities

What Happens to:

Archeological sites / Cultural Landscapes	Riparian ecosystems
• Greater erosion to archeological sites nearest to river. • Loss of cache pits due to increase in soil moisture. • Loss of ethnographic resources • Increase in potential pocket gopher activity	• Increase in cottonwood recruitment • Decrease in piping plover nesting success • Increase in waterfowl production • Increase in siltation (negative) – leads to decrease in storage capacity behind reservoir • Loss of riparian areas to ag. fields
Upland Grassland	Facilities / Infrastructure / Other
• Decrease in upland nesting success • More warm-season grasses • Possible increase in “new” invasive species – cheat-grass… • Loss of grasslands to ag. fields	• Damage to roads / buildings / trails • Decrease in durability of buildings (increase in moisture) • Increase in cost to dam repair / maintenance

ND Scenarios: 2015-2050______Severe Sustained Drought (Little Hell on the Prairie) __

In your scenario:

Regional Climate Features:
• Most Warming (+ 4 degrees) • Most drying • June-October decreased precipitation • Decreased winter / summer flooding • Variable soil moisture followed by 10 year drought (spring/summer dry)
What socio-political developments might occur alongside the climate changes?
• Missouri River Politics • Decreased water for fracking • Decreased interest in recreation on water • Increased demand for irrigation water – possible shift to drought tolerant agriculture • Decreased tourism • Decreased hunting opportunities for waterfowl • Increased competition between water users (urban, rural, industrial)

What Happens to:

Archeological Sites/ Cultural landscapes	Riparian ecosystems
• Increased probability of fire therefore discovery of additional sites • Low water – archeological sites revealed • Change in vegetation therefore change in rodent excavation • Decreased archeological erosion –fewer large flood events • Decreased ice dam events	• Decrease in trees, increase in tree mortality – lack of recruitment in riparian areas • Increased concentration of large herbivores creates more impact on remaining wetlands / water areas • Increased invasive species • Decreased native and wetland species • Decreased carbon sequestration
Upland Grasslands	Facilities / Infrastructure
• Temperatures increase C4 (warmer season) grasses favored • Increased probability of fire and wind erosion • Decrease in cool season invasive species • Increase in warm season invasive species • Decreased forage wildlife / cattle • Decreased carbon sequestration	• Decreased hydropower • Intakes go dry • Increased upstream capture • Water infrastructure high and dry • Increased danger of destructive fire

Appendix 3. Testing Decisions Worksheets

This appendix is provided so that participants of the workshop can review their workgroup exercises and to provide ideas for others wishing to use scenario planning.

Management Topic: Cottonwood Forest in KNRI

Adaption Strategy	Goal / Objective	Scenario 1: Warm with Wet Summer = Least Change	Scenario 2: Hot Summer, Soggy Spring (ND++) (good for cottonwoods)	Scenario 3: Hot flood See-saw (good for cottonwoods)	Scenario 4: Severe Sustained Drought (Little Hell on the Prairie)	Summary Across Scenarios
Resist Change	• Keep the cottonwood forest and its dynamics as close to historical as possible	• Fight increase in flow • Minimize riprap Costs/Trade-offs: • Relocate infrastructure away from river • Loss of cultural sites - mild	• Fight increase in flow • Minimize Riprap Costs/Trade-offs: • Relocate infrastructure away • Loss of cultural sites - moderate	• Fight increase in flow • Minimize riprap	• Mechanical treatment to encourage reproduction Costs/Trade-offs: • Possible failure because of limited water • Archeological sites fare better	• Major conflict with archeological resource preservation. (least under little hell scenario) • "Heavy lifting" – requires resources
Direct Change	• Manage conversion of some stands to other native-dominated communities adapted to emerging conditions	• Similar to Hot Summer, Soggy Spring but less intense (because of fewer floods) • Reduced ash, favors bur oak and boxelder	• Irrigation • Riprap specific archeological sites • Deer management • Acquire easements riverside land • Plant cottonwood or mechanical treatments	• Riprap (Max!) specific archeological sites • Deer management • Acquire easements riverside land • Plant cottonwood or mechanical treatments	• Irrigation • "artificial (mechanical) erosion "creating a flood plain" • Embrace grassland in some places • More bur oak than boxelder	• Can preserve archeological resources • Most costly

Adaption Strategy	Goal / Objective	Scenario 1: Warm with Wet Summer = Least Change	Scenario 2: Hot Summer, Soggy Spring (ND++) (good for cottonwoods)	Scenario 3: Hot flood See-saw (good for cottonwoods)	Scenario 4: Severe Sustained Drought (Little Hell on the Prairie)	Summary Across Scenarios
Accommodate Change	• Support autonomous conversion of cottonwood to other native species	• Control exotics (Russian olive)	• Control exotics (Russian olive, tamarisk)	• Control exotics (Russian olive)	• Control exotics (Russian olive, tamarisk) • Embrace grasslands	• Least costly (redefining success) • Could get species that do poorly in the future • Cottonwoods confined to small areas • Still have a bottomland forest in all but little hell scenario
Preferred option in the scenario. Why?		• cottonwood: direct change preferred but will cost money • archeological: direct change most preferred	• cottonwood: resist change preferred • archeological: direct change preferred	• cottonwood: resist change preferred • archeological: direct change	• cottonwood: accommodate (b/c cottonwoods not likely to succeed) • archeological: direct change	• Challenging exercise • Resources available is key determinant (partnerships!, grants!) • Archeological resources limit management flexibility • Garrison Dam is an influential legacy • T/E spp (plover) also significant on the Missouri River

Management Topic: Vegetation Components of the Cultural Landscape

Adaption Strategy	Goal / Objective	Scenario 1: Warm with Wet Summer = Least Change	Scenario 2: Hot Summer, Soggy Spring (ND++)	Scenario 3: Hot flood See-saw	Scenario 4: Severe Sustained Drought (Little Hell on the Prairie)	Summary Across Scenarios
Resist Change/ Current approach	• Keep all native species where they are now and restore non-native areas	• Green ash / cottonwood in riparian zones • Reduce invasive species • Native mesic mixed grass prairie	• Green ash / cottonwood in riparian zones • Reduce invasive species (more control needed) • Native mesic mixed grass prairie • Prescribed fire in fall • Mechanical thinning	• Green ash / cottonwood in riparian zones • Reduce invasive species • Native mesic mixed grass prairie • Prescribed fire in fall • Mechanical thinning	• Not achievable under this scenario	• Little tweaks to hold the line in three of four scenarios
Direct Change	• Enhance populations of culturally important species	• Continuing conversations with tribes to determine priorities	• Continuing conversations with tribes to determine priorities • Native tall grass prairie • Irrigation system • More invasive control	• Continuing conversations with tribes to determine priorities • Demonstration plots of a range of culturally important species • Native tall grass prairie • Irrigation system • Use mechanical or fire to control woody encroachment • More invasive species control	• Continuing conversations with tribes to determine priorities • Demonstration plots of a range of culturally important species • Irrigation system • Plant drought-resistant genotypes / species • Less invasive species control	• Refuge
Accommodate Change	• Let it go where it wants to (without too many invasive species)		• Woody encroachment – allow desirable species but not on archeological sites	• Woody encroachment – allow desirable species but not on archeological sites	• Less forest • Encourage native prairie where trees die –less fire?	• Adaptability of management and stakeholders • Need to decide what KNRI is as a park

Adaption Strategy	Goal / Objective	Scenario 1: Warm with Wet Summer = Least Change	Scenario 2: Hot Summer, Soggy Spring (ND++)	Scenario 3: Hot flood See-saw	Scenario 4: Severe Sustained Drought (Little Hell on the Prairie)	Summary Across Scenarios
Preferred option in the scenario. Why?			• Adaptability	• Adaptability	• Species refuge	• Need to decide what KNRI is as a park

Management Topic: Archeological Sites

Adaption Strategy	Goal / Objective	Scenario 1: Warm with Wet Summer = Least Change	Scenario 2: Hot Summer, Soggy Spring (ND++)	Scenario 3: Hot flood See-saw	Scenario 4: Severe Sustained Drought (Little Hell on the Prairie)	Summary Across Scenarios
Resist Change/ Current approach	• In Situ Preservation	• Maintain bank stabilization and expand where needed Costs/Trade-offs: • Road or trail damage • Destruction of cottonwood habitat • Large boulders in river bed increase turbulence and erosion • Increased hazard for boaters	• Maintain bank stabilization and expand where needed • Flow modification, channelization • Mechanical removal of vegetation Costs/Trade-offs: • Destruction of cottonwood habitat • Prescribed burns (not at ideal times)	• Maintain bank stabilization and expand where needed • Flow modification, channelization • Cut new river channel or diversion channel Costs/Trade-offs: • Destruction of cottonwood habitat • Sacrifice some archeological sites • Road relocation	• Maintain bank stabilization and expand where needed • Water / irrigate vegetation to maintain riparian vegetation stabilization Costs/Trade-offs: • Destruction of cottonwood habitat	• Pocket gophers changes unknown • Plan for variability / extremes in all scenarios
Direct Change **(proactive)**	• Maximize information (research archeology)	• Use research design to target areas for information gathering Costs/Trade-offs: • Destroy site	• Use research design to target areas for information gathering Costs/Trade-offs: • Destroy site	• Use research design to target areas for information gathering Costs/Trade-offs: • Destroy site	• Use research design to target areas for information gathering Costs/Trade-offs: • Destroy site	• What constitutes an archeologica l site?

Adaption Strategy	Goal / Objective	Scenario 1: Warm with Wet Summer = Least Change	Scenario 2: Hot Summer, Soggy Spring (ND++)	Scenario 3: Hot flood See-saw	Scenario 4: Severe Sustained Drought (Little Hell on the Prairie)	Summary Across Scenarios
Accommodate Change **(reactive)**	• Collect available (basic) information (salvage archeology)	• Salvage archeology Costs/Trade-offs: • River destroys some sites	• Salvage archeology Costs/Trade-offs: • River destroys some sites	• Salvage archeology Costs/Trade-offs: • River destroys some sites	• Salvage archeology Costs/Trade-offs: • River destroys some sites	• Not preferred • Salvage archeology is a bad plan
Preferred option in the scenario. Why?		1. In Situ Preservation 2. Research to monitor for vulnerabilities and priority area	1. Research archeology 2. In Situ Preservation (fund research instead of bank stabilization)	1. Research archeology 2. In Situ Preservation (fund research instead of bank stabilization)	1. In Situ Preservation	• In Situ always part of the portfolio Challenges specific to archeological sites: • Can't change – only degrade at different rates • Don't have "genetic modification" option or introduction of new species.

NPS 909/133729, August 2016

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov